A guidebook for co-creating community-based internet and data hubs

Introduction

Today, access to the internet is considered a basic service. In 2016 the UN General Assembly passed a non-binding Resolution that declared internet access a human right. It is essential for connecting people, conveying and getting access to data and information. With the hit of Covid-19 globally and the need for physical distancing, the internet emerged as essential to keep systems like education, business, and health running. Internet accessibility greatly determines socio-economic and political opportunities as well as individual well-being. However, it is still largely spread unequally throughout the world, and low-income communities in developing countries are the most disadvantaged.

In addition to internet access, the lack of access and control over the data collected about them is another big challenge faced by underserved communities. Despite being the ones who know their issues best, their voices are still left unheard. Informal settlements are marked by extractive research with little contribution to improving people's quality of life. Data is often collected independently of residents, excluding them from immediate benefits and control over their narrative. Data today represents the knowledge and power to speak with evidence and advocate with ownership. The Internet is crucial for collecting, managing, and sharing data; therefore, internet access and affordability matter.

Aware of the challenges around internet and data access in under-resourced settings, we produced this guidebook to help different communities and organizations worldwide deploy community-based internet and data hubs to help address both the internet affordability and infrastructure gap. A community-based internet and data hub centers on community co-design for sustainability and provides communities access, ownership, and control over their data. It engages in training selected community-based organizations on how to set up a community Wi-Fi network, manage it, financially sustain it, and the benefits of gathering, analyzing, sharing, and using community data.

We have put together a detailed and illustrated six-step guide to help you understand the information you need to gather, the questions you need to ask, and the actions you need to take regardless of your internet or data skills. We recognize that no universal approach applies to all, so we present each step as a reference guide to help you tailor the process to your needs and local conditions. We will share examples from the Living Data Hubs project to help you better understand the process in practice, including some of our common challenges and the lessons we learned.

The Living Data Hubs (LDH) is a small-scale information, communication, and data management project launched in January 2020 in the informal settlement of Kibera in Kenya. Kibera is amongst the largest informal settlements in the world and the largest one in Kenya, house of a population ranging between 235,000 and 270,000 inhabitants (Map Kibera, 2019) and characterized by limited basic services and infrastructure, including water, drainage, waste management, sanitation, stable electricity, and affordable Wi-Fi access. The settlement is also vulnerable to climate risks such as flooding and poor air quality, posing additional health risks to the residents. Kibera is one of the most documented informal settlements in Africa with a large NGOs and researchers presence over decades and thousands of studies published on Google Scholar and other research platforms. But their residents are frequently overlooked in collecting data about them and their neighborhoods by external researchers and development practitioners.

LDH installed a community-based wireless network across four community public spaces representing diverse and multifaceted groups of people with different identities, ages, literacy levels, backgrounds, and motivations, bringing different perspectives about data collection and internet use in the community. Through an international development partnership, LDH facilitated capacity building to support digital literacy, financial management, and network sustainability. Through this guidebook, we hope that the LDH experience also helps strengthen the advocacy for equitable access to internet services and the use of data to amplify the voices of the most vulnerable and marginalized people.

As you go over the six steps listed below, we would like you to remember that they don't work isolated and that it is important to have a broad overview of all the aspects at the beginning and continuously discuss them throughout the project to inform good decision making. For instance, as we soon learned in the LDH project, the equipment to buy and the systems selected highly dictate which data can be collected and how, which services can be provided and to whom, and the maintenance needs and costs of the network. You may also need to think about additional requirements depending on the specifics of your project design, location, and goals.

Guidebook structure and content

understanding of community data and internet networks	internet networks among partners? How to understand community patterns and challenges to help design a functional, useful, and meaningful network for residents?	
Part 2: Understanding the requirements to build a computer network	What essential factors determine how communication happens in a community network? What are the necessary components to build a community internet and data hub? How to choose the correct equipment for the network?	
Part 3: Understanding the existing infrastructure and site challenges	What knowledge about the existing infrastructure is essential to planning your network?	
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Step 4: Maintaining and managing the network	How to take proper care of your network to ensure good service? How to guarantee sustainability in maintaining and managing the network?	31-35
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Step 1: Building partnerships and making connections within the community

Overview

A community-based internet and data hub attempts to shift the power in who designs, implements, owns, and maintains infrastructure in resource-poor communities and presents new approaches by building local partnerships to co-design the network and its uses. Therefore, establishing strong partnerships is the first step toward a successful and sustainable community data and internet network. This chapter will highlight important features to consider when forming a team and essential aspects to discuss and agree on to align your mission.

Identifying partners to work with

Each organization's experience is essential to meet the project goals. Partners need to be fully engaged and committed to the objectives and able to allocate people and time to the project. A strong partnership needs to consider the following skills, backgrounds, and capacity:

Local network and knowledge - At least one of the project partners should have experience working with similar contexts and have a physical presence across different spaces in the specific community. They need to be a trusted community partner who can facilitate connections and interactions with community-based organizations (CBOs) and leverage their experiences from previous projects to facilitate community engagement.

Technology knowledge - One of the project partners needs to work within the digital field, with interest in social innovation and technical knowledge, to help develop and support the construction and maintenance of the community-based internet network infrastructure, side-by-side with CBOs.

A service provider - This can be either a community Wi-Fi network, a non-profit, or a for-profit provider depending on the business model the project will follow (find more about the business model in Step 6). For deciding on a service provider, you can use an internet sourcing survey to understand existing providers, their service rate to determine affordability, and their level of presence in the community, including the satisfaction of existing subscribers. The partner should have the network infrastructure and capacity to provide good bandwidth and stable connection for an adequate number of users simultaneously, according to the project's purpose. Reliable internet is essential for project success.

Research skills - One of the partners should have technical resources and the capacity to create, transform, and transfer knowledge and technologies. They should be able to gather and analyze qualitative and quantitative data to support informed decision-making in the project. They can help build a better understanding of available options, design better approaches for working across multiple partners and vulnerable communities, and develop strategies for participation, surveying, training, and facilitation.

Interested CBOs - Community-based organizations are the network's final owners, and their active engagement can guarantee the project can be successful and sustainable on its own. An ideal CBO partner will be well-established and work with the immediate community and be interested in using the internet and data to help address challenges in their neighborhood.

Important reminder: You may have one organization that holds many of the abovementioned skills. For instance, an NGO can both have local experience and also have research experience. That can work if they have enough people and resources to allocate to the project. Be mindful of institutional calendars as they vary from institution to institution and region to region. If you are working with an academic institution, you should have a plan for how to manage work during academic breaks. When working with international partners, you should consider holidays in their countries.

Mission alignment

Mission alignment will help create an efficient project framework, establish effective processes, and help everyone direct the resources and expertise to achieve the project's goals. A few considerations can help your team build and sustain your mission throughout the project.

Set a common goal - It is important to set a common goal and make sure everyone understands the idea of the project or program you want to establish. This requires opening space for questions and suggestions and reaching agreements about values, approaches, and what is feasible within the available timeframe and budget.

Discuss the budget and accounting - Working across partner groups requires a clear budget estimate and an accounting system that defines where the funding is coming from, what expenditures are covered and by whom, and how disbursement and financial accountability will happen. Essentially, the budget must account for materials, labor costs, training, and equipment needed from all the partners involved. If international partners need to be physically present at the project location, the budget can also consider travel costs. Partners may need to work together to write grant proposals and secure funding for the project.

Establish a timeline - You need to agree on a project timeline, negotiate dates and activities, and discuss roles and responsibilities for each partner and other stakeholders involved, such as residents. Activities will range from who leads the meetings to who leads the installation of the internet infrastructure.

Establish a working schedule - The team should agree on a regular meeting schedule at a comfortable time and place for everyone. In-person or virtual, this is a moment where all partners convene to report and discuss the ongoing activities and next steps. Regular meetings help keep partners informed and involved, realign the mission, manage expectations, and keep up with the timeline. Smaller groups can set up meetings as required to plan training, discuss specific issues, or coordinate internal activities.

Prioritize capacity building - Despite the previous experience, some partners may need to further understand a few aspects of the project or learn and improve additional skills to better contribute to advancing the project goals. Thus, for a community network to succeed, everyone must access the needed capacity. Capacity-building needs will vary across partners, and you need to acknowledge and assess them to tailor training as much as possible. Continuous capacity building is also a great strategy to keep partners involved as expectations may change as the project progresses.

Promote effective communication - Good communication is key to project efficiency and should be cultivated from the beginning of the partnership. It helps build trust, increases cooperation, contributes to informed decisions, and to promptly address any unforeseen situation. Along with regular meetings, you can take advantage of digital channels that can facilitate interactions between the team. You can create a Slack workspace, a Whatsapp group, or email threads to instantly communicate delays, report technical difficulties, share uncertainties, give an announcement, or just coordinate specific tasks.

Example of the LDH experience

Partnerships

Living Data Hubs is an international collaboration between Kounkuey Design Initiative (KDI), community-based organizations (CBOs) in Kibera, TunapandaNET (TNET), and the Massachusetts Institute of Technology (MIT).

KDI is a design non-profit working in Kibera since 2006 with community partners on the Kibera Public Space Project (KPSP). KPSP is a network of eleven public community sites that CBOs and Kibera residents use for meetings, organizing, celebrations, and other physical, social, and economic needs. KDI leads community engagement with CBOs who own and operate the public spaces that comprise the KPSP. Having KDI in the team, a trusted community partner, facilitated connections and interactions with CBOs. In LDH, KDI led community engagement with the CBOs based on their experiences from previous projects in Kibera.

T-NET is a community Wi-Fi network and social enterprise run by Tunapanda Institute since 2018 in Nairobi. They run technology, design, and business training courses in East Africa. TNET has been a key player in global conversations about community networks. When the LDH project began, TNET had already started providing free internet to schools and organizations in Nairobi and was expanding and developing a business and payment model for a larger internet provision. Within the project, TNET not only provided internet to the sites but also supported the construction and maintenance of the network infrastructure and systems.

The MIT team consisted of two labs in the Department of Urban Studies and Planning. The Civic Data Design Lab (CDDL) works with data for the public good and develops alternative practices to make data and images richer, smarter, more relevant, and responsive to the needs and interests of citizens traditionally on the margins of policy development. CDDL had already been successful at working toward the generation of missing transportation data through their work on the Digital Matatus project in Nairobi. The City Infrastructure Equity Lab (CIEL) focuses on the governance of the financial architecture behind urban infrastructure projects and how it matters to the distributional fairness of benefits and the health of marginalized communities. CIEL works to identify practical policy levers that better foreground equity in both processes and outcomes of local urban development interventions. CIEL has worked with local authorities, national governments, and international organizations in Africa, Asia, and Latin America. Beyond KDI, TNET, and the CBOs, all based in Nairobi, MIT was based in the United States and worked remotely to support the project through management, training development, design, research, and coding.

Four of the eleven community sites on the KPSP network participated in the LDH pilot.

CBO Name	Description
VIjana Usafi Na Maendeleo (VUMA)	VUMA is an entrepreneurial youth group that co-designed and manages KPSP 11. The site features a community hall, water kiosk, water tank, playground, and sanitation block that builds on and upgrades existing facilities operated by the youth. VUMA works hard to address flooding issues and create job opportunities for community members. They have been actively building their capacity to manage complex, community-driven sustainable

	development processes to support a more prosperous future for themselves and their community. Vijana Usafi na Maendeleo means Youth for Sanitation and Development
Anwa Junior Academy (Anwa)	Anwa, KPSP 8, is a primary school founded by a group of mothers in Kibera. They worked with KDI through a participatory process engaging local youth to provide skilled labor and respond to the need for improved learning facilities in Kibera as a fundamental component of sustainable development. The new school building has been operational since 2017, providing a safe, flexible, and pleasant learning environment for 400 children ranging from 2-to 14 years.
SUN Centre: Ndovu Development Group & Usalama Bridge Youth Reform	KPSP 4, the SUN Centre is a site run by two CBOs, Ndovu and Ussalama, designed to respond to flooding, youth unemployment, trash, pollution, and insecurity. It is home to a sanitation center, a childcare program with a playing area, and offices serving hundreds of residents. Usalama is a youth group establishing a new boda boda taxi service to further increase their economic opportunities and improve mobility for the Kibera community. Ndovu is a women's group operating a baby care collective and various income generation projects. Together, the groups lead community clean-up along the riverbank, promote landscaped recreational areas, and improve drainage channels to reduce flooding.
Andolo Bridge Community (ABC)	ABC runs KPSP10, a space designed to test, evaluate, and refine the Productive Public Space model as a comprehensive strategy to reduce flood risk in informal settlements while incorporating the community's wider economic and social priorities. The site features a flood-protected landscape, playground, water tank, laundry area, shaded seating, kiosks, and a community space to host activities and events. ABC also includes a pedestrian bridge, improving the current access path.

CBOs were selected through a request for proposal (RFP), a democratic decision-making process used by KDI for all their new projects and already familiar to all CBOs within the KPSP. The RFP document included a diagram to clarify the written document and clearly explained the project objectives, timeline, eligibility, and evaluation criteria. We held meetings to explain the project further and answer any questions CBOs had before applying.

In general, the following steps guided the RFP process:

- All CBOs within the KPSP invited to apply for RFP
- KDI held meetings with interested CBOs
- CBOs submitted RFP applications
- Applications reviewed by the other partners and shortlisted
- Follow-up interviews with groups on the shortlist
- Five CBOs from four KPSP selected.

We made all decisions through a concrete, transparent, elaborate, and comprehensive approach and communicated every action to all applicants. We selected the best proposals for further development based on the evaluation of the following indicators:

1. Area - future projects with impact on the area, existing land conflicts, and local politics;
2. Strength of the proposal - all questions answered with logic, coherence, and credibility;
3. Project potential - scope, scale, impact, equity, sustainability, and maintenance;
4. Site and technical feasibility - accessibility, safety, existing activities/services, group agreement, line of sight, users threshold;
5. Group capacity - leadership, group track record, history of community cooperation.

		Describe how you intend to utilize/ what you might intend to achieve with wireless internet service should it be provided	*Select up to four points related to internet access that you think are most important to your CBO and your community?*	*How will the project bring social and environmental benefits to you as a CBO and the community?*	*How would you ensure sustainability of the LDH project and maintenance of internet-related infrastructure?*
Organization	Structure	Proposed Project Details	Importance of internet connectivity	Potential Benefits	Sustainability
Usalama Bridge Youth Reform	Chairperson, Vice-chair, Secretary, Vice Secretary, Organizing Secretary, Treasurer, Committees: Oversight, Executive, Welfare, Disciplinary	Since the group intends to venture into the transport industry, it will help us advertise the business online, tracking bikes, communicate between the business management and KDI representative and also in doing research for business expansion	Addressing community needs through COVID-19. Equitable access to affordable internet. It is created and operated by the local community working together as an organized group with residents and other groups. Adds value to space without alienating the original community.	The vulnerable committees will easily access the internet. Children can also access online learning to access the internet.	We will sign one of our members to be in charge of the internet and give them the full support required to perform their duties.

Example of response summary from one of the selected CBOs

Managing expectations and setting up timelines of implementation

LDH dedicated to ensuring everyone understands the idea of the project by holding meetings both in Swahili and English, the two most commonly spoken languages in Nairobi. The meetings offered open space for questions and suggestions to build a collective understanding and reach agreements about what could be done and achieved within the two years of the project. For instance, all partners were clarified that this would be a community internet with shared bandwidth, limiting businesses such as cyber cafes or video streaming. The quality of the internet would depend on how CBOs governed its use to ensure the shared resource is available for everyone.

In terms of capacity building and sustainability, LDH clarified that it would provide general information for the entire CBO but was only able to train three members of each, and they would have to teach the rest of their team. Most importantly, we agreed that access to the internet network would be free of charge for CBOs during the testing phase but would require payments afterward, so we had to make efforts to make sure CBOs understood the operation and management costs of the network.

Despite the initial conversations and agreements, we faced several constraints throughout the project. Internal changes in organization structures and turnovers greatly impacted the project timeline. We have also learned that the expectations changed as the project progressed. We learned that proper documentation of information and structures for knowledge transfer help make the transitions smoother; continuous training with the community is essential to keep them involved and effectively build capacity.

Project budget and accounting system for working across partner groups

LDH was funded by the DAR Urban Research Seed Fund, and the budget was managed by MIT. The fund covered materials supply, training, network equipment, internet connection for the testing phase, and labor costs for MIT research assistants, KDI researchers, and TNET technicians. The project did not fund the attendance of workshops and meetings and ongoing maintenance costs.

MIT provided a spreadsheet template to fill by all the partners detailing the budget estimates. With travel restrictions due to the Covid-19 pandemic, the budget was reviewed and funding for trips was relocated to compensate for the additional efforts needed from the partners in Kibera. All the network infrastructure equipment was scoped by Tunapanda and purchased by MIT.

Working schedule and leadership of meetings among partner organizations

The team agreed on biweekly meetings led virtually by MIT with the participation of TNET and KDI to report on the ongoing activities and next steps. Each organization had a leader and different people involved in the project who would also participate in meetings, report on their involvement, and contribute to the general discussions, making it easier to follow up and meet deadlines. Smaller groups would meet as required to plan training or discuss specific issues. The organizations, individually, also met biweekly to coordinate internal activities.

We created different digital channels to facilitate communication and coordination between the group. Apart from emails, we used a Slack workspace with various channels. A large WhatsApp group was also established as a more accessible platform to interact with CBOs in the KPSPIN. CBOs could report any concerns about the project or the network after installation through this platform. Nevertheless, we later learned that despite CBOs' involvement through meetings, training, and surveys, they should also have a seat at the table and regularly participate in team discussions for a more inclusive approach that would also facilitate expectations management, accountability, sustainability, and decision making throughout the project.

Step 2: Building capacity and understanding for effective network planning

Overview

Building capacity and understanding is one of the project's most important parts and demands more time and attention. It helps partners grow in comfort with using and managing the network and understanding the importance of promoting equity in internet and data access. To achieve project goals, you may need to conduct several activities, including surveys, meetings, and training with all partners, and engage with community members to understand their needs and receive their invaluable input. The activities will also help you get information to better shape the project and plan the network's technical parts.

The second step focuses on three essential parts of capacity building that will help you effectively plan your network:

1. Building a common understanding of community data and internet networks
2. Understanding the requirements to build a computer network
3. Understanding the existing infrastructure and site challenges

Part 1 - Building a common understanding of community data and internet networks

There are varying levels of information and knowledge about technology. When starting up a wireless network project, you need to equalize that knowledge and equip partners with the necessary understanding to engage more substantially in conversations around the network's governance, management, and sustainability. As the first step in capacity and understanding building, you need to start by training everyone in basic concepts of data and the internet, including aspects around the structure and functionality of a community network. Below are the things we find important to explain to the partners.

Explaining data and community networks

We define data as information, a collection of facts such as numbers, words, measurements, observations that we record and can translate into knowledge. Today, data can be easily shared and accessed through the internet. People can also use the internet to communicate from anywhere in the world using electronic devices such as cellphones and computers.

Using the internet, you can create community networks to socialize, communicate, exchange information and resources, support education, promote entertainment, foster advocacy, and boost the local economy in the community. When you have a network set up in a community, you can also access content that you all create for each other without needing access to the global internet.

Use of data and internet for the community

The project should be meaningful and useful for the community and help improve their quality of life. So, to get a sense of what types of data the community is interested in, CBOs and general community members should together reflect on how data would be helpful for their community and provide their invaluable input. The decision about the type of data to collect will guide how the network is designed and the choice of equipment, with a great impact on the costs, management and maintenance needs, and network sustainability.

The following questions can help guide the reflections:

- What information/data would you like to collect for the project? How will the information collected be used to support the community?
- Think of problems or challenges you face in your life or workplace. What kind of information might be needed to solve these problems?
- What potential or opportunities exist for CBOs and communities to sell their data?

It is also important to understand current internet use among community members and discuss how those may or may not fit in the purposes of the community network. The questions below can help guide the discussion:

- When do you use the internet on a typical day?
- What are some of the apps and websites you use the most?
- What do you think we should use the community internet for?
- What do you think the internet should not be used for?

Establishing network using standards

To guarantee good bandwidth for everyone, the network committee needs to establish usage standards by listing restrictions and values. For example, the network may discourage clients from using attention-intensive applications like YouTube, Netflix, or online games. It may be necessary to block access to websites and applications over the network.

Example of the LDH experience

In the LDH, explaining concepts was one of the first steps needed to open the conversation about the importance of the internet and data for the communities and actively engage partners during the project. We explained concepts and discussed them collectively using examples and recreating visuals found daily in Kibera. For data, we provided examples such as spatial, weather, and financial figures. For internet networks, we used social networks and how they compare to internet networks as an example.

To get a sense of what types of data the community was interested in and help plan the network, we hosted several meetings with community members to understand their challenges and get input on what data would help address them. CBOs brainstormed how they use data daily, and the themes that came out of the meeting included education, business, microfinance and record-keeping, communication, and transportation, amongst others. Regarding the problems faced in daily life that the internet and data could help address, the CBOs brought up information sharing, low business income, thefts and insecurity, and high prohibitive internet access costs. Additionally, we discussed current internet challenges and uses in Kibera and how they would like to use the internet to add to the collective public spaces and everyday lives.

Both information from the meetings and the Request for Proposal process was considered in defining data priorities, including from CBOs not selected for the pilot. The community in Kibera was primarily interested in data about the environment and health, specifically about weather conditions, air quality, rain and flooding, surveys about health, and locations of health centers. Most residents use and support using the internet for socializing, communicating, learning, business transactions and advertising, getting information, and checking the weather. They agreed on restricting or limiting heavy attention apps and websites, individual movie downloading, racketeering, and other malicious or improper activities. CBOs would affix use standards on each site, use website blocking, and monitor constantly.

The findings of the initial meetings helped formulate our Community Data Plan, a document designed as part of the efforts to have the opinions and preferences of the community reflected in the network system and address the systemic issues around extractive research in Kibera. The plan focused on environmental and health data, considering project limitations such as ease of maintenance of the system and relevance to the donor (learn more about our Community Data

Plan in step 5). The Community Data Plan allowed us to better plan the network and document the project progress.

Part 2 - Understanding the requirements to build a computer network

Once you understand community data and internet networks, it is time to get some technical understanding of how computer networks work, including the components needed to build one. Despite the wide variety of structures, equipment, and systems, it is important to understand how to make the best choices for your site based on your needs, specifications, and costs.

Understanding computer networks

Computer networks can be compared to social networks and how socializing, communicating, and relating to each other happens in society. Social networks connect people, and computer networks connect devices. Several factors will determine how devices can talk to one another and share information and resources in the network. For a community-based network, the following factors are essential:

A. Structure
B. Topology
C. Modes and rules for communication
D. Language
E. Barriers to communication
F. Roles and responsibilities
G. Trust and good relationships

A. Structure of a computer network

A computer network have components, equipment and systems, that we need to identify and understand to build it. Those components are interdependent, and decisions made about equipment should be aligned with decisions about systems as each system works better with only specific equipment. To allow better integration between community needs with the software and hardware, decisions are first informed by the agreements about the network purposes, specifically the types of data to be collected and the uses and restrictions of the internet.

A computer network requires five main components: the internet, the antenna, the access point, and the clients.

<u>Internet</u>: is a technology that allows devices to communicate over any distance. It must be provided by a trusted and reliable provider with the network infrastructure with the capacity to provide good bandwidth and stable connection. Reliable internet is essential for the project to be successful.

<u>Antenna</u>: allow devices to speak to each other over different distances. It helps send and receive Wi-Fi signals from remote locations to local sites. Examples of different types of these devices include sector antennas, omnidirectional antennas, and point-to-point receivers. You choose your antenna according to the type of speaking and listening power you need between devices.

<u>Access Points</u>: are devices that host and control the wireless connection, providing access to clients, ensuring that only those who have access can join and use the network, and keeping clients safe and secure when using the internet. **Routers** and **switches** work as access points (APs) and play a significant role in sending and receiving messages by acting as the bridge between clients and the internet. APs can cover a range of areas with a wireless signal, depending on the device's power and the antenna type. Different types of routers have different power levels. Some have good speaking power, and some are good listeners. The farther a listening router is from the speaking router, the weaker the signal it can hear. You can use both indoor and outdoor routers as APs in each site to provide internet access. Outdoor APs should be weatherproof and designed and mounted in a location that will allow clients to connect within the desired range.

<u>Clients</u>: are devices that connect to an access point to gain access to the network. Devices such as computers, tablets, and phones are typical clients, but smart TVs and other devices that can speak Wi-Fi language can also be included. When you are accessing a wireless hotspot, your device is a client.

To host antennas and routers, you need equipment hosting devices. They are physical structures that help position networking devices so that they can ‘’see each other’’ with fewer obstructions. Some hosting equipment help in keeping the network devices safe from unauthorized access while offering a safer way of handling devices. Some of this equipment includes masts, racks, and fans.

Getting the right components for your network is essential to avoid continuous changes that eventually make the network unstable and unsustainable. Before purchasing devices and equipment, you need to consider the following aspects:

Local availability - should be locally available and have spare parts readily available for easy maintenance and updating.

Local power - should consume less energy and not add a cost burden to the network.

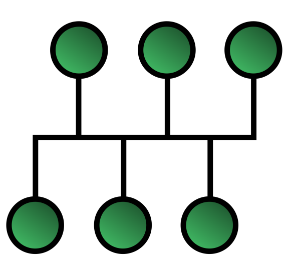
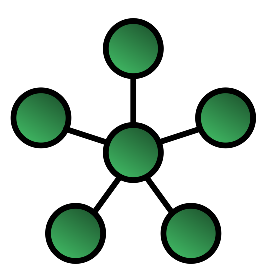
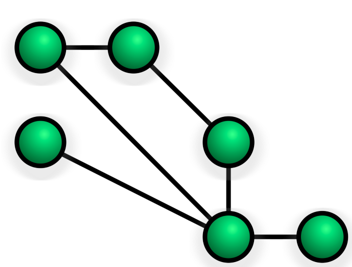
Low cost of deployment - should not be expensive to deploy.

Less complex to use - easy to set up, maintain, and debug.

Low learning curve - should take someone less time to learn how to operate.

B. Network topology

A network topology is a structural design that allows the formulation of the typical relationship between devices and segments of the network. It is important to survey all the community sites to inform the kind of network topology needed according to the physical conditions of the locations. You can opt for one of the following types:

Bus/line	**Star**	**Mesh**
Each network device is connected to a single cable.	Each network device is connected to a central node such as a router, hub, or switch.	Each network device is interconnected with one another. There is a full and a partially connected mesh.
It requires less wiring and works well for small networks.	A single point of failure does not break the network. Good for large networks.	A single point of failure does not break the network. It manages high amounts of traffic. Wiring depends on the number of nodes.
Difficult to identify or isolate failures in the network.	More expensive due to the need for extensive wiring.	Building and maintaining are difficult and time-consuming.
		

C. Modes and rules for communication in a computer network

All social groups have many ways to communicate, such as via email, face-to-face, or letters. They also have rules about who can and should speak to who. For example, in big companies, only the CEO or other executives can speak to the board. Devices in a computer network can communicate in two ways:

Wireless connection - The term Wireless means without physical wire and implies that signals can be transmitted from one end to another without using wires. It requires the Access Point and any device that wants to use the internet to use a type of radio called Wi-Fi. It is the less costly option for community networks and, therefore, the focus of this guidebook.

Wired connection - A wired connection supports communication between two devices by connecting them with a cable, supporting devices that do not have a Wi-Fi radio.

There are three main rules for communication:

1. Access points can only connect over a wired connection.
2. Clients don't speak to each other directly; they need access points to communicate.
3. Access points and clients can connect over a wireless or wired connection.

D. Language in a computer network

It is difficult to build strong social ties when language differences exist. We understand many of our close friends because we speak the same language. Wi-Fi is the main language in a community network. Only equipment and devices that can speak and understand Wi-Fi can participate in Wi-Fi networks; therefore, all the equipment you set up needs to speak Wi-Fi. Devices like smartphones, tablets, laptops, and some smart TVs can speak Wi-Fi.

E. Barriers to communication

In social groups, big and small, many factors can make communication difficult; governance issues, distance, age, and language differences are some examples. It is important to identify these factors and manage them to ensure the social network is strong. The same is true of computer networks, and we have identified some barriers to communication and important aspects to consider during the design and planning phase.

Barrier to communication	Consideration for planning and design	Learnings from the LDH/KPSPIN[1]
Line of sight - Devices must be able to have an unobstructed view from one to the other.	Are there any trees obstructing the view of the transmitter site? Is this site at the bottom of a hill? Are there large built structures that are impeding or blocking the signal between the transmitting and receiving antenna?	ABC is located at one of the lowest points of the settlement and couldn't get a clear line of sight from Tunapanda signal transmission points. Thus it has been quite challenging to get reliable and stable internet access at this site. To manage this challenge, we collaborated with the Hope School next to ABC for internet access. The school is located on a higher elevation and thus gets better connectivity.
Weather - Rain can interfere with communication between devices, especially when the network is not robust.	Is the weather usually wet or dry?	CBOs experience internet failures on heavy rain days.
Power - The equipment will not work if there is no power supplied.	Is there a constant and reliable power source for the antenna and router?	Due to the lack of legal power sources at most sites, the KPSPIN setup relies on solar power. Because it limits connection on continuous cloudy days, there are efforts to establish legal sources of power and install automatic switches such that the solar becomes a backup where possible.
Interference and network range - Devices can still communicate with little interference. With a lot of interference, the devices get very confused.	Are there other organizations in the area using the same technology? Are there large bodies of water around this site? What is the outdoor and indoor range of the network at the site?	We have faced several range issues at many sites, especially with the outdoor Wi-Fi. There must be robust range checks when setting up the network to understand access areas and communicate expectations with the community.
Distance - Devices usually can't communicate over very long distances. We need to give them better antennas to allow devices to communicate over long distances.	What types of devices can be used for what situations? Which areas does the community want to be connected to? How does the district between these areas affect how the network looks?	Sites that are further away from the network transmitters are challenging to connect, especially in a mesh network that is relayed wirelessly.

[1] KPSPIN is the name CBOs participating in the LDH collectively decided to name the community network, an addition to Internet Network to the already existing Kibera Public Space Project.

F. Roles and responsibilities in the network

Understanding and assigning roles

To build and take care of the wireless network, you need CBO members to understand and assign management roles to the network committee. There are many ways to organize the network roles within different CBO structures. You can choose to organize roles like CBO Committees or differently. One person can take on the responsibilities of one role, or multiple individuals can share responsibilities. CBOs should collectively decide which structure works best for their site. There are three main roles for CBOs members to take on:

- The **organizer's** role would be to lead the network committee, conduct general management tasks, and engage with project partners. They need to be someone comfortable with holding community meetings, bringing people from the community together, managing the hub, and engaging with partners.
- The **handy person** is someone comfortable at tinkering, building, and fixing things. They might also be familiar with connecting electricity and procuring/bartering for hardware/equipment. For example, a woodworker, blacksmith, or even a cobbler. The handy person will be the main responsible for installing the network and maintaining the hardware.
- The **techie** is someone more familiar with software and computers, either via formal or informal experience. This individual will primarily act as a network administrator and interact with the interface. They will focus on troubleshooting arising network issues and managing operations, including contacting and requesting assistance from the different partners and changing passwords when needed.
- The **organizer**, handy person, and techie need to be trained on the network and will ideally stay involved in the organization for more than a year to benefit their site with the knowledge and skills acquired.

Filling Gaps for Roles

If you already have CBO members to fill all roles, you will be ready to build and manage the network. If you don't have people within the CBO to fill each of the roles, there are two options:

- You can look for someone in the CBO who might agree to take on the role but does not have the training yet.
- You could pull expertise from another CBO.

G. Trust and relationships

Trust is vital for social ties. Building strong social networks is challenging if we can't trust each other. Our existing relationships help us build new friendships and expand our network. This social thinking can also be applied to internet networks like community Wi-Fi. If devices on a computer network cannot trust each other, then no communication will be able to happen, and the network might be jeopardized or corrupted. You can use passwords to allow unknown devices to access and use the network. When you give a password to someone to access the internet through the network, you affirm your trust in them to do good things on the network.

Example of the LDH experience

After a thorough survey of the sites, including the understanding of the geography of the community and elements that could pose barriers to communication, such as the landscape, water bodies, trees, and buildings, we decided that a mesh topology would be the most appropriate for our network because it distributes wireless communications across vast areas without requiring extensive wiring, making them ideal for community hubs.

TunapandaNET was selected as the internet network provider, having installed internet to more than ten institutions in Kibera. TNET provided the backhaul for the infrastructure. They connect to KENET, a government internet supplier, which provides a subsidized internet to support community-based internet initiatives. We could support the four internet hubs with TNET bandwidth at 15mbps per site. Still, we needed to actively seek to increase network speed and reach through a backhaul connection to improve and expand access to allow the development of more sustainable business models.

Our decision on the systems and equipment for the KPSPIN was informed by the kind of data CBOs and the community was interested in collecting and visualizing through polling and the user's agreements. T-NET played a lead role in specifying the equipment to be used on site. The first contextual consideration was to use equipment procured in Nairobi and often used by T-NET, allowing for easy maintenance and updating. We used a Wi-Fi antenna at each site as a signal receiver and two indoor and outdoor routers to provide internet access. The outdoor router is weatherproof, designed to be mounted on a tower, and able to connect with client devices on a site very far away since the dishes face one another. The antenna was attached to a mast.

For roles and responsibilities, a schematic chart illustrating four different structures that might work best for the different KPSPIN roles was presented to the four sites. The task was for CBOs to discuss and decide which structure they feel most comfortable with and would better adapt to their existing organizational structure. Each CBO selected members to take on the role of the organizer, the techie, and the handyperson for the KPSPIN committee. They established that each role would go through a new selection process annually. Since Usalama Bridge Youth Reform and Ndovu Development Group shared a site and they would be sharing equipment, they decided to work together as a shared committee and have an additional techie and organizer to ensure both CBOs had representatives. ABC opted to add a vice organizer and combine the techie and handy person roles.

While it was important to have this structure of roles in the CBOs, throughout the project, we learned that the political organization of CBOs can change sporadically, driven by changes in the community and local politics. Thus, structures for knowledge transfer in the CBOs need to be in place for when such changes occur.

Part 3 - Understanding the existing infrastructure and site challenges

Network planning includes understanding the infrastructure ecosystem in the location you are about to install your network. You need to understand the strengths you could leverage and potential factors that could affect your network and define strategies to mitigate the issues early.

Electricity sources

The router (and in some cases the antenna) requires an electricity source to operate. Therefore, it is important to ensure that devices are properly and sufficiently powered to support access. The power supply needs to be reliable, legal, and stable. You need to perform a survey to understand electricity usage in your site focusing on the following aspects:

- Identify and document the types of power sources;
- Document the location of locally available legal connections;
- Identify and document all equipment that would need to be powered in case of a power outage or power disconnection;
- Identify and document all equipment currently using power on-site;

- Determine potential future uses on-site;
- See past utility bills and calculate how much energy is consumed in a day;
- Determine the amount of solar energy needed to fully charge back-up batteries in a day;
- Determine what would be an ideal uninterruptible power supply to install in the site;
- Determine the capacity of batteries needed to power the equipment and how long the equipment would be able to supply power in the absence of other power sources.

If stable and legal power supply means are unavailable, you can explore other options to power up the network infrastructure. Following are some alternative strategies:

1. Work with existing solutions while exploring alternatives in parallel
2. Work with CBOs and begin the process to secure legal access
3. Set up off-grid solution (short-term mitigation)
    - Option 1: Contract local solar microgrid provider
    - Option 2: Design and deploy solar battery system
    - Option 3: Procure a solar battery system
    - Option 4: Use rechargeable batteries
4. Set up off-grid solution (long-term mitigation)
    - Option 1: Contract local solar microgrid provider
    - Option 2: Procure a solar battery system

You will need to weigh all your options considering the pros and cons using criteria such as expected time of deployment, reliability, upfront and operation cost, conflicts, local availability, efficiency, and skillset.

Space requirements

A space to house the network equipment should be safe, both in terms of vandalism and nature-based threats. You need to explore the suitability of locations in each site to ensure efficient operation and management of the network. You need to identify and secure suitable spaces that could house the router and rooftops that could anchor the antennas. For the router, the space needs to be away from smoke, dust, moisture, and heat, while for mounting the antennas, the rooftop needs to be strong and with an orientation away from obstacles to avoid interference. Be careful of rooftops that are too steep and choose a safe location to avoid injuries to the technicians during mounting or maintenance.

Next, you should discuss the different safety and security issues and how to prevent them, including the threat of theft and vandalism. You may need to place the router in a metal mesh encasing or house the solar battery in a closed box. These measures also ensure that the network equipment is not accidentally powered off.

Regulatory framework

To implement your project, you should be aware of any local or national regulations that impact your activity. You may need to secure licenses or permits, and costs may vary according to the business model you decide to set up. In some communities, there may be local leadership structures that may need to be informed or consulted. Before setting up the network, you need to have all legal requirements fulfilled to avoid additional future penalties.

Example of the LDH experience

In the LDH, we performed a survey to understand electricity usage and space availability across the KPSPIN. Information was collected based on observation and personal interviews, with at least two respondents per site. It was important to clarify some terms used in the survey to avoid misinterpretations.

The survey revealed that some KPSPs had no access to electricity, others had an unofficial connection, and others had a full connection to legal electricity. The team decided to ensure that all sites had reliable electricity by installing solar panels before setting up any Wi-Fi infrastructure, which considerably delayed the project's timeline. The solar system was capable of powering the equipment while the process of setting up legal access was running in parallel.

Regarding space to house the equipment, T-NET explored the suitability of locations in each site to ensure efficient operation and management of the KPSPIN. All sites had feasible locations, and we moved to discuss with CBOs the safety and security issues each site had and how to address them. For example, since SUN Center had the active presence of various youth groups, there was a high threat of vandalism to the outdoor router. We thus placed the router in a metal mesh encasing. At most sites, the router and solar battery were housed in a closed box to avoid unintentional vandalism or accidental power off of the equipment.

Concerning regulations, Kenya requires profit-based internet providers to pay four major fees: one-time incorporation of CBO fee, yearly business permit, licensing, and operating fees. Non-profit organizations like the CBOs in the KPSPIN only needed to be formally registered as community-based organizations.

Step 3: Installing the wireless network

Overview

After a series of training, discussions, and agreements about the community hub, the next step is to build the physical structure to start operationalizing all the project ideas and objectives. Installing the wireless network is the physical result of a collaborative process that engages every partner and community in determining the technology, electricity source, and selecting the spaces for the equipment installation. It is the beginning of the opportunity for communities to start implementing all the learnings from the training and capacity building. Follow in this chapter the step-by-step to mount the internet hub structure.

Installation training

The network installation is preceded by training and workshops to help CBOs understand the network architecture and build capacity to conduct the installation without needing to master complex engineering concepts. The pre-installation training provides a step-by-step explanation of building a computer network and the basics of taking care of the network, such as safety and use standards. It allows participants to interact with the equipment to be installed at their sites.

Six steps to establish a network

Once you have completed the design, plan, and purchase of equipment for the network, it is now time to install it and ensure everything is working properly. For that, the technology and internet provider partners along with the organizer, techie, and handy person of CBO committees will work together. You also want to test and ensure that the network design is reliable and sufficient to meet the users' needs.

In summary, these are the five steps to install a network:

A. Mount the equipment

B. Configure the equipment

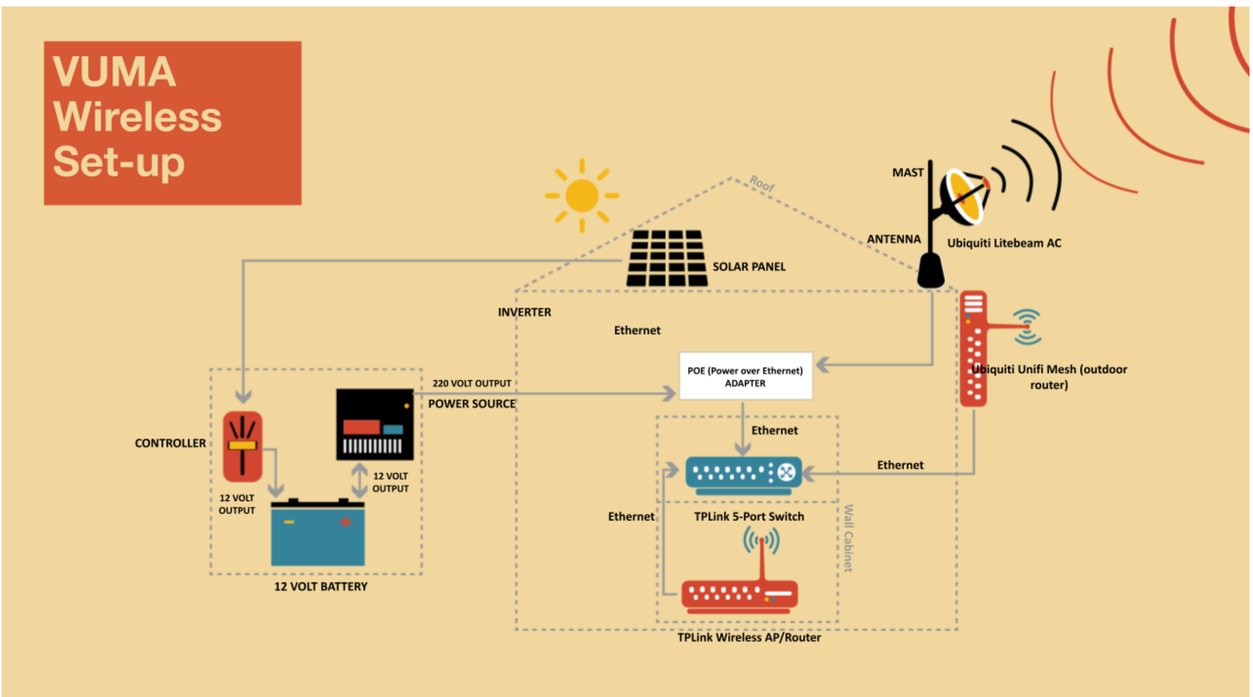
C. Keep the equipment safe

D. Education on proper access and use of the network

A. Mount the equipment

There are the three essential steps to mount the equipment:

1. The masts must go up to the rooftop, high enough to ensure there is not too much interference;
2. Attach the antenna to the mast and guarantee it is steady and has a good line of sight to the transmitting antenna;
3. Connect an ethernet cord from the antenna to the router and a power source to create a wired connection between the two devices[2];



Equipment setup at one of the KSPIN sites where solar panels were required

B. Configure the equipment

After the antenna is connected to a power source and the router, you can now start up the router and configure it to work. Some of the things you will be doing in equipment configuration are allocating bandwidth, setting the network name, creating a password for the router, and

[2] In this setup, you can only connect to the antenna through a wired connection to give the router access to the internet and allow it to provide to your space as a wireless internet connection.

giving the router a unique identifier that will allow you to give access to the network to other devices. We recommend using strong passwords to secure devices and gain access to the network. Every router comes with its own router management portal, which has the capabilities to manage users, set passwords, and administer the network. It is handy to get a basic understanding of the router management portal. (learn more about network management in Step 4).

C. Keep the equipment safe

Make sure equipment is only accessible by those responsible for managing it. Always keep the equipment in the condition and position placed during installation. Ensure the network is always plugged in and the power is switched on (in our experience, this is a common cause of internet outages).

D. Education on proper access and use of network

Educate users on how to access and correctly use the equipment. Ensure that the internet is used for non-malicious purposes and install site blockers as needed. Provide instructions to members and users on watching out for scams online. Make sure to give passwords appropriately to trusted users. Place internet troubleshooting guides at the sites for basic troubleshooting and daily management of the network.

During the installation process, it is important to note the possibility of using the network to collect important data, including the need for the current or future installation of data collection sensors. At the KPSPIN, we installed air quality sensors.
Remember that you will need to set up an off-grid system if no legal and reliable power supply is available

Step 4: Maintaining and managing the network

Overview

Computer networks require a lot of care and maintenance to ensure good internet and data services and guarantee sustainability. For many community-based Wi-Fi networks, achieving long-term sustainability has proven to be an elusive goal because they often cannot bear maintenance costs and lack the technical knowledge required for upkeep. We present in this chapter a guide that the community can use to easily manage and maintain the physical structures and systems of the network and reduce dependence on external stakeholders.

Network Equipment Maintenance

There are essential considerations about network equipment maintenance for a community internet network. Here are three essential strategies to enable CBOs to work independently and troubleshoot and fix common network problems.

1. The use of locally procured equipment that the community can easily maintain and is already familiar to the technology partners responsible for providing maintenance assistance whenever needed.
2. Capacity building about equipment maintenance, including the provision of resources for helping CBOs establish a maintenance plan integrated into the business model.
3. Good governance of the sites, ensuring responsibilities for site maintenance are assigned in CBO's governance structure. You can decide between one representative or collaborative leadership.

Checks on power supply

When power is cut off, CBOs need to restart the router when power is back on to re-establish the connection. They also need to make sure that the equipment is always connected to power on a daily basis. You can better monitor if the equipment is connected by installing a single switch than by having multiple switches.

Equipment repairs and replacements

It is important to know how often to check equipment for malfunctions (and resolve them immediately) and when to replace them. Each piece of equipment has an expected life span that should be acknowledged and planned for by each CBO. While routers usually need to be replaced every five years, antennas are only expected to last for two to three years, and purple air sensors need replacement every two years.

Network Management

Network management is the process of administering the setup and usage of computer networks. You need network management to:

- Track issues and problems with network devices and resolve them as quickly as possible;
- Control users' access to the network and collect payments;
- Prevent malicious actors from disrupting network activities.

To operate and manage your network, you will need the following systems:

Network Administration System - a mechanism for monitoring the performance of your network devices from one central point. These systems create a virtual representation of the physical network in a more user-friendly interface that allows network administrators to easily troubleshoot basic network problems and control network usage. Some access points already come with a management system that you can use, or you can also build your own management system.

User Management System - is a software program that can help manage the users by automatically sending them emails, messages, or voice calls to authenticate access and allow them to pay for internet usage. This system needs to be installed on all your sites and is essential to keep control when the number of users expands and it becomes challenging to physically attend to everyone or account for their activities in the network. You can write your own software, pay for one, or use open sources that match your needs (see Appendix A for a list of useful open source and paid options).

Network administration

Some access points already come with a management system that you can use, or you can build your own management system. Here we give an example of the TP-Link router system, including its functionalities and limitations.

TP-Link routers come with their own management portal that offers a menu with various functionalities and a Quick Setup Help guide for each feature that is easy to understand and navigate. CBOs could create and manage network administrators through the platform, allowing access to the router web interface and settings only to specific identified and trusted devices with management roles to perform router settings. The portal allows administrators to:

- Check the summary of all the network settings;
- Setup the network connection, including operation mode, wireless configuration, and security;
- View information about users and wireless statistics;
- Test whether the router is receiving network connection or not and check network strength;
- Add limits (time, distance, devices, bandwidth) to network usage;
- Set up router software updates.

In terms of limitation, TP-Link Router assigns DHCP Server to allocate 99 sets of IP addresses by default. This means that TP-Link can only serve its best when no more than 99 devices are connected to the router at a given time. There is only a certain amount of connectivity shared among all the users on the network, and allowing more devices to connect to the router simultaneously may negatively impact the quality of service and performance, for instance, the internet speed each user gets.

User management

An effective and holistic approach to managing users in the network is via a captive portal, a web page displayed to new network users before allowing access to its resources. It can be used as a hub for users, allowing them to access the network, contribute to current research projects, and view relevant data about their communities, all in one location. You can write your own software, pay for one or use open sources that match your needs. In making that decision, you should consider the following core capabilities:

- Network access management, for example, through a log-in and signup page;
- Payment platform to allow users to pay to access the internet securely;
- Data collection and share.

Example of the LDH Captive Portal

Designing the Captive Portal: Wireframing

We worked with a team of programmers from the University of Nairobi to build the captive portal, starting by building our initial ideas for wireframes and sketches for the captive portal. The general design of the platform was relatively simple and incorporated colors and similar illustrations used for the other training and materials. The developers created a web application optimized for mobile devices, allowing it to be used across different smartphone models.

The basis of the platform was first to brand the network to ensure the community-facing internet access point was recognizable across all sites and digitally integrate the internet aspect into the data collection aspect of the project. Thus, we illustrated how different data could be collected and shared on the platform beyond prototyping the landing page. The community discussions to determine the most relevant data to their needs led us to design data viewing options for localized air quality, weather, and health information.

Core Capabilities - login, survey/payment, and free information

The interface was divided into three sections: first, the home screen, which integrated the login and sign-up page. Then the survey section, which could collect information about health or education within the community. Finally, we incorporated a landing page that allowed community members to explore and understand the data collected through the network.

The home screen includes a simple login and sign-up page to ensure users only accessed the survey once. After the home screen, users would proceed to another page, allowing them to choose if they want to take a survey or pay to access the internet for a given amount of time. If users decided to take a survey, they would receive complimentary 10 minutes of browsing time, and we would be collecting data through the network. If not, they would buy a plan to use Wi-Fi for a set period through M-Pesa. After either taking the survey or paying to access the network, users would be directed to the landing page, which would allow for browsing and access to information and the data collected through the network.

Platform Considerations - Typeform survey and payment

The survey is an essential part of the web platform we developed, as it allows researchers to obtain valuable information from the Kibera community. The survey was also integrated into our sustainability model, incentivizing continued user participation with free Wi-Fi.

We needed our survey platform to be user-friendly for both the participants and the survey creators. For the participants, this meant support for multilingual surveys, mobile friendliness, and varied embedding options. Survey creators, however, needed the ability to interact with survey results via an API or visualizations, data export, ease of survey creation, and the ability to track user participation metrics (completion rate, time spent per page, etc.). Typeform met these needs and was chosen (Step 6 gives a detailed description of the Typeform survey as part of the data collection model, a fundamental part of the project's data action).

To ensure our network provision business model's sustainability, we needed to create a way for the users to pay for network access reliably and securely. M-Pesa, a Kenyan electronic payments service, was the obvious choice, as it is almost ubiquitous in Nairobi and allowed us to issue tokens to enable network access. Negotiation with Safaricom, the Kenyan mobile network company operating M-Pesa, is lengthy and costly and significantly impacted our project timeline. See Appendix B for the list of the processes and documents needed by a CBO to obtain an organizational pay bill to facilitate integrating the business component into the captive portal in Kibera.

Step 5: Collecting, managing, distributing, and using data

Overview

People on the margins of society tend to be bypassed by researchers and policymakers. They lack access to data collected about them and are, therefore, excluded from immediate benefits and control over their own narrative. The collection, management, and distribution of data are one of the most valuable assets of a community network, contributing to the prioritization of community interests and promotion of community data ownership, giving them the voice and power to use it for their benefit. This section will help you design a data collection setup that meets your community's needs and improves network sustainability.

Community data and action plan

You can create a community data and action plan to systematize, document, and guide you through the data collection, management, distribution, and use process in a way that is impactful for the target community. There are three essential points of a data and action plan that we will further guide you through below: community data priorities, data collection infrastructure, and data distribution and use. Be mindful that each point will require specific actions such as training, discussions, or research.

Community data priorities

This step will allow you to define data priorities focusing on having the opinions and preferences of the community reflected in the system and empowering residents to hold access and control over data about them. It will also allow you to manage potential differences between what will interest CBOs and what will interest the broader members of the community. Here are three useful criteria to evaluate and decide on data priorities for your network (see additional resources for collective data decision-making in Part 1 of Chapter 2).

- Relevance to the community - make sure to include opinions and preferences of the community as the most relevant criteria for topic selection;
- Ease of maintenance - make sure that systems and equipment needed to collect and manage data are easy to operate and maintain;

- Relevance to the donor - depending on how your project is funded you may need to account for the donor's goals.

Data collection infrastructure

After deciding on what kinds of data to collect, it is time to work on the infrastructure you could use to collect that data. Here we will share two easy tools that can easily be incorporated into the internet network: surveys and sensors.

Surveys

You can use surveys as a tool to get community feedback on various topics important to CBOs, the general community, or other clients such as outside researchers, government entities, and NGOs.

To make the survey easily accessible to residents, you need to make sure to:

- Present in the most spoken languages by the community;
- Provide context and details about the topic;
- Explain the purpose;
- Inform about the number of questions and the estimated time for completion. We advise that surveys be short to encourage completion and safeguard quality;
- Inform what users will get from taking the survey, which can be free internet access for a certain amount of time.

Typeform

The Typeform survey can be embedded into the captive portal webpage, sparing the need for complicated backend maintenance and security protocols. User responses to the survey can be logged in a survey creator portal, which provides great flexibility in data interaction and viewing options, including a fully-featured API for programmatically interacting with results and Google Sheets Export functionality.

You may deploy one or multiple surveys at a time. Host one survey at a time facilitates tracking of user activities.

Sensors

Sensors are small devices that can be easily attached to wireless hotspots to collect different environmental and health data. Examples include air, noise, temperature, humidity, pollution, and motion detectors. One type of environmental sensor easy to use in community networks is the PurpleAir sensor. Poor air quality is one of the top environmental and health concerns in urban areas, and many communities lack the required data to understand the extent of the problem and its impact on their daily lives.

The PurpleAir is a device with an approximately one-year lifespan that can be easily installed, monitored, replaced, and connected to the Open AQ platform. It can be placed indoors or outdoors and detect particles suspended in the air of various sizes (PM1, PM2.5, PM10), including dust, smoke, and other organic and inorganic particles.

Data is collected and reported by the PurpleAir sensor every two minutes. It is stored on ThingSpeak API for free and can be visualized by locating the device in the PurpleAir website map. Data can also be retrieved through a simplified automated process. You can write a computer program through Google Apps Script to automatically download the air quality data to the appropriate spreadsheet by running a script every 5 minutes. This computer program will send a request to the OpenAQ API and write that data to the appropriate Google Sheet. The computer program starts a new spreadsheet if the Google Sheet reaches a certain size. If a new sensor is added to the configuration Google Sheet, the computer program will create a new Google Sheet to start storing data for that sensor. Google sheet is an easy option to visualize data requiring only a Gmail account.

CBOs need to be trained on how to install, connect, register, and retrieve data from the PurpleAir sensors. Depending on your project timeline, you can have this training along with the network installation training or at another time. This training will allow community ownership of air quality data from sensors placed around the local community. You can find all the information you need about understanding and installing PurpleAir sensors on the official website www2.purpleair.com.

> You will need to have someone from the network committee responsible for periodically updating and downloading the air quality data. You can have a handbook with simple step-by-step instructions.

Data distribution and use

Despite this history of engagement and research, data has generally been collected about residents of vulnerable communities rather than with or for them. Subject to the control of researchers and international organizations, much of the data collected remains outside the control of residents. In this model, you should guarantee that the data collected is shared back with residents in easy ways for them to access and understand.

You can design an interactive internet landing page that acts as a community platform for data collection and visualization for data collected through surveys and sensors. Residents can access this information for free from a mobile phone or computer in the language they are most comfortable with, regardless of whether they are paying or not to use the internet.

CBOs should hold ownership and control over their neighborhood and community, and they could use the information to advocate for themselves or share it with outside researchers. Researchers would pay for the service, which would help CBOs recover costs. CBOs could also charge third-party organizations to use the network to disseminate important information to the community. See more details in Step 6 about the business model.

Example of the LDH data and action approach

The community data and action plan in the LDH focused on environment and health topics, piloting with data collection through surveys and air quality sensors. Data priorities were collectively defined based on an extensive community engagement process with training, discussions, surveys, site visits, and physical assessments. The construction of a new road that passes through the center of Kibera by the Nairobi Metropolitan Services (NMS) offered a great opportunity to collect valuable data through the survey and the sensors.

We designed a survey to assess the impacts of road construction on people's lives and assess the extent to which there was public information and engagement of residents in the decision-making process. The survey was presented in both Swahili and English. As we tested the survey, we learned from the responses the need to reduce survey length and clarify some questions for better outcomes. MIT trained KDI in how to create, customize and share survey results using the Typeform platform so they could assume leadership of the process and train CBOs later. The training included a guide through the steps to deploy the survey to the KPSPIN web platform hosted in Heroku using GitHub.

We used PurpleAir sensors to respond to the existing demand for health and environmental data in Kibera and address residents' concerns about poor air quality, mostly from cooking and the new NMS road construction. We first studied the many initiatives implemented in Nairobi to learn from them and denote their weaknesses. One of the biggest issues was that most air quality sensors only last three months, and we needed a way to provide longer access to data. We used a PurpleAir PA-II sensor, a device that lasts approximately one year and can be easily installed, monitored, replaced, and connected to the Open AQ platform. We agreed that the techie or manager of the CBO would be responsible for updating and downloading the air quality data on the first of every month. They would go over the handbook and follow instructions to download PurpleAir data into a Google Sheet to view data and create graphs. If researchers want to add a different kind of air sensor, they need to follow KPSPIN system requirements. The CBO techie would follow the management handbook to install and uninstall the sensor after the agreed period expires.

Step 6: Designing a sustainable business model for the network

Overview

Business models are a key aspect of community-based network upkeep and growth for long-term sustainability. It is important to develop innovative business models to sustain the internet to support the development of businesses and institutions that utilize it to create new services like educational services, streaming services, delivery services, etc. This section elaborates on what innovative business models you can develop to sustain the network, support the building of local economies, and open up new possibilities for underserved communities. It will also walk you through important costs to include in your budgeting.

Sustainability guidance

At the beginning of the project, you need to examine possible sustainability business models for community-based internet projects in similar challenging contexts, including specific examples to understand the potential opportunities and challenges of internet provision and take timely measures to address them. You need to account for fixed, operational, and maintenance costs, understand the cost to users and estimate revenue for financial sustainability using different models. Through engagement with local partners, CBOs, and communities, your project can gain more contextual inputs about what model would be useful and sustainable, what leadership structures could be leveraged, and what regulatory frameworks need to be considered in developing a sustainable business model that could be easily scaled up. You will need to understand current internet prices in the area and the potential number of users you will have.

Business models

You should analyze the cost recovery from both nonprofit and for-profit models' perspectives in line with activities CBOs are currently doing or anticipate doing in the future.

1. **Non-profit business model**

In a non-profit model, CBOs can only use money from sold internet services to maintain the service by covering equipment and maintenance costs, i.e., labor, system management, and additional fees. That means customer charges should be equal to the total cost of service. If customer charges are greater than the sum of service costs, CBOs can reinvest those funds into the business, which would still be considered non-profit. CBOs could also adopt a non-profit model and still charge for indirect internet use, such as streaming a game or other services that are not directly providing the internet but use the internet and make a profit.

A non-profit model offers the least expensive option with less probability of price increase in the near future. If working simultaneously with multiple sites, some costs may be shared for the whole network.

2. **For-profit business model**

In a network with profit purposes, CBOs could use money from sold internet services to sustain the service and reinvest into the CBO or distribute it to members as profit.

A for-profit model can be expensive depending on the services you aim to provide. It requires more bandwidth, and if you plan on running a cyber cafe, it will require the purchase of more computers. It also needs to account for additional fees and taxes to pay to the government.

Understanding costs and budgeting

Regardless of the business model you choose, you will need to account for the following important costs to keep your network up and running:

Fixed cost - this is the initial upfront cost to buy equipment and systems to build the network. From a sustainability perspective, it is important to buy equipment easy to find locally for easy replacement and compatible with the overall network infrastructure, both existing and new, to avoid unnecessary additional costs.

Operational cost - CBOs need to account for government and other fees that need to be paid to operate, cost of servers, electricity, and online security. This cost depends on the business model adopted, as for-profit organizations are usually required to follow a more demanding regulatory framework and acquire all the necessary licenses to operate. If not paid, high fines and legal consequences are applicable. You also need to pay for a contract to enable a pay bill platform for users to pay for internet access.

Labor cost - Each CBO needs at least a member to supervise internet access and upkeep the network. CBOs can decide whether to pay the member and how much per month.

Maintenance cost - Maintenance of network equipment and systems is an important part of sustainability. Costs vary, but CBOs need to set regular savings to cover future costs. Estimates are made based on the lifespan of equipment and estimated repairs and replacement costs.

Systems usually require a regular subscription fee. You can use open-source management systems to avoid the additional expenses of paid platforms.

Internet cost - Costs of the internet are usually estimated on a monthly basis and vary depending on who provides your internet connection, what purpose you will use it for (profit or non-profit), and what speed of internet connection you need. You should compare costs from different providers in the area. Remember that a service provider is a partner and will need to be engaged in several processes during your project, and internet reliability is essential to help CBOs develop a sustainable business model.

Deciding costs of internet usage

Decisions on how much to charge customers for internet usage result from a reflection and analysis around questions and hypothesis testing for cost recovery for CBOs. Based on the total monthly network costs, you need to estimate how many hours of internet connection you would need to sell a month to keep the network sustainable. Based on the average number of users, you can estimate how much each user would have to pay, how much they are currently paying, and how they are willing to pay. You can also test alternatives based on daily, weekly, and monthly internet plans.

Data sharing and revenues with research organizations

You can leverage your community-based internet network as a financial resource for residents to host and facilitate research initiatives in their neighborhoods and collect important data using data collection sensors and surveys. CBOs can resell data to researchers or interested firms. Remember that sensors must also be regularly maintained and replaced according to their lifespan.

Example of the LDH Business model

The LDH model differentiates itself from existing community-based internet hubs through its business model and co-development process, which promotes the financial and management sustainability of the community-based networks. LDH leveraged a unique business model that advances access to affordable internet services through community-based networks, empowers residents with a platform to collect-control-sell data, offers digital literacy, and expands access to economic opportunities to community members.

At the beginning of the project, we examined existing sustainability models for community-based internet projects in low-income communities across the world, including in Sub-Saharan Africa and Kenya specifically. We also conducted user-centered research with community input through surveys, site visits, and exchange visits to similar projects in the area. We decided to use a non-profit model, which offered the least expensive option with less probability of price increase in the near future and the possibility of sharing some costs for the whole network.

LDH covered the initial upfront costs to build the network and the monthly fees for all the CBOs during the pilot phase, including equipment, internet, and systems. As nonprofits, CBOs only needed to be formally registered as community-based organizations. Security costs were jointly negotiated within the monthly internet fee with Tunapanda. We also needed to pay for a contract with Safaricom to enable the M-Pesa platform for users to pay for internet access. In terms of labor, it was left to the discretion of each CBO to decide whether or not to pay the member responsible for taking care of the network.

After analyzing the internet costs of internet providers in the area, we chose Tunapanda, a non-profit based in the community that could provide help when needed, during and after the pilot. TNET offered a significantly discounted price for an internet speed that would allow for basic internet surfing and video streaming-like usage to open more business possibilities to CBOs, i.e., streaming movies and football matches. Unfortunately, several barriers to communication not properly addressed in the planning phase greatly impacted connectivity in some of the sites and delayed the implementation of the business model.

We needed two servers for hosting data, an online server for hosting the captive portal, and a local server for local data storage. We installed a server at the TNET office in Kibera to centralize surfing and data storage. The place was safe and reliable and had a sufficient power supply, including a ready power backup for prolonged power outages. This storage cost was determined based on storage requirements and was evenly shared among the four CBOs in the KPSPIN. Other shared costs included the Typeform survey, which used an annual subscription fee for hosting surveys on the platform, and the bi-annual update fee for the website that presents the PurpleAir quality data.

To allow users to pay for internet use, we decided on an M-Pesa pay bill facilitation system with Safaricom, which included an individual contract cost for a commercial account and an SMS subscription for the captive portal. The SMS service is prepaid and uses a recharge-based model with deductions made per SMS. Gathering all the necessary documentation from CBOs and negotiating a contract with Safaricom is a lengthy and costly process and greatly impacted our project timeline. Alternatively, while waiting for the pay bill, some CBOs would give passwords to known people from the community and collect cash payments. This option made it difficult to control users and required constant changes of network passwords.

Appendix B - process to obtain an organizational pay bill in Kibera, Kenya

Category	Item name	Purpose	Source	Cost	Duration
External Requirements	1. M-PESA account opening authorization form	Mandatory form that must be duly filled and sent to Safaricom to request for account opening	Safaricom	Printing & Scanning costs Up to Kshs 100	2 Days
	2. PAY BILL USSD Application form	Mandatory form used to open ussd services to allow one to perform transactions using ussd, e.g., * 234#	Safaricom	Printing & Scanning costs Up To Kshs 100	2 Days
	3. M-PESA SERVICE Application form	Mandatory form that must be signed and stamped by the main signatory of the group bank account in requesting either PAY BILL or TILL services. -It contains T&C of the services	Safaricom	Printing & Scanning costs Up To Kshs 100	2 Days
	4. C2B Pay Bill Tariff	Mandatory document showing different tariff/plans that an organization can pick. It must be signed/stamped	Safaricom	Printing & Scanning costs Up To Kshs 200	2 Days
Internal Requirements	1. Request Letter	This is an official letter with organization letterhead addressed to Safaricom describing the nature of your organization and business and why you request an account opening. Must be stamped	Organization/ CBO	Printing & Scanning costs Up To Kshs 100	2 Days
	2. Business / Organization/CBO Certificate of Registration	This requirement is needed to authenticate that the said business entity is recognized.	Organization/ CBO	Printing & Scanning costs Up to Kshs 100	2 Days
	3. Organization KRA + individual KRA Certificate	For sole proprietorship, you must attach a personal kra certificate. -For organizations, they prefer business/organization/ CBO KRA + Individual certificate only for the group bank account signatories.	Organization/ CBO	Printing & Scanning costs Up to Kshs 100	Obtaining new certificate Between 15-30 days
	4. Bank Account	-Bank account will be the primary place to settle your funds collected through PAY BILL.	Organization/ Bank	NIL	Opening a new account -

		- You will be required to attach a canceled check or proof of account opening letter from the bank.			1-7 Days
	5. Official Stamp	This will be required to authorize all documents.	Organization/ CBO	Khs 2000.00	2-3 Days
	6. Email Address	For communications and transfer of documents, you need a valid and active email (preferably organization email)	Organization/ CBO	NIL	Opening new account 1 Day
	7. Technical (IT Personnel)	For API integration, M-Pesa service management (M-Pesa portal). These require someone with a little background in IT	Organization/ CBO	Negotiable	Flexible
	8. Bank Signatories Details (At Least 3)	- Copies of National ID Numbers - KRA PIN Certificates - Functional mobile numbers (Preferably Safaricom Simcard) - Individual KRA pin	CBO/ Organization	NIL	Flexible
	9. Finance Officer	- National ID - KRA PIN Certificate - Working Safaricom number	CBO/ Organization	NIL	Flexible
	10. Resolution Letter	- Letter with letterhead giving an official statement that authorizes the process of obtaining M-Pesa Services. NB: Must be stamped and signed by Directors (At least 3)	CBO/ Organization	NIL	Flexible
	11. Pay Bill SIMCARD	-Used to manage all pay bill transactions and check whenever a payment is received	Safaricom/ Safaricom Shops	Kshs 150	24hrs
	12. M-Pesa Portal Activation	Send an email to Safaricom via <M-PESABusiness@safaricom.co.ke> and cc <business.support@safaricom.co.ke> to activate the M-Pesa portal for your organization.	CBO/ Organization	NIL	3 days?