Chapter 21
Connecting Communities Through Mobile Networks: A Case Study of Implementing Community Cellular Networks in the Philippines

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1 Introduction

No recent technology has had a greater impact on economic development than mobile networks, which comprise the largest networks on Earth and cover over five billion subscribers. Cellular networks have allowed easier access to communication and information crucial in making informed decisions about education, employment, social and entrepreneurial activities, and other aspects of daily life. Mobile coverage gaps often exist in remote, rural areas, sometimes called the "last mile" (or "first mile") of connectivity, where the typical economics of providing network service do not hold (Cherry, 2003). For-profit companies often find it difficult to justify expanding coverage to areas where profits are low due to the large investments required for traditional cellular infrastructure, for example, places where the potential subscriber base is not large or wealthy enough to recover the total capital and operational expenditures (CapEx and OpEx) involved in ongoing operation. In addition, many remote rural areas lack the supporting infrastructure needed for cell networks, such as stable grid electricity and a network connection back to the global Internet, called "backhaul." Furthermore, technical support and maintenance for these networks is often slow and difficult due to the long distances that network support engineers, typically based in city centers, must travel to provide service.

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T. Madon et al. (eds.), *Introduction to Development Engineering*,
https://doi.org/10.1007/978-3-030-86065-3_21

To address these coverage gaps, the cellular infrastructure and operational model must be redesigned, taking the aforementioned issues into account to make deployment in remote areas more economically viable. The CoCoMoNets project (Connecting Communities through Mobile Networks), implemented jointly by researchers at the University of the Philippines Diliman (UPD) and international research partners, tackled the challenge through **community cellular networks (CCNs)**. CCNs fall under the broader domain of community networking – an alternative approach to standard telecom service in which communication infrastructure is built by or with local people who will use the network (Song, 2017). The researchers designed a low-cost GSM base station that allows voice calls and text messaging at a fraction of the capital and operational costs of traditional cell networks. To address the challenges around maintenance and support, local community members and community structures were involved in the deployment, operations, management, and ownership of the network (Bidwell & Jensen, 2019).

This chapter documents the research team's experiences and challenges as they attempted to pilot community cellular networks in the Philippines from 2015 to 2019. Despite initial successes, they encountered barriers to continued operation which led them to ultimately shut down sites or pivot to Wi-Fi Internet access networks.

This chapter is organized as follows. First, Sect. 2 presents an overview of the project and its context. Section 3 narrates the challenges and implementation experiences, and a discussion of open challenges for CCNs follows in Sect. 4. Section 5 closes with a summary and conclusion.

2 Innovation

2.1 Technology

Designing cellular network infrastructure for rural areas requires careful consideration of its context. First, many remote areas in the Philippines do not have access to reliable grid electricity, so the network equipment's power consumption must be low enough to be supported by off-grid renewable energy systems. Second, backhaul Internet connectivity is expensive and intermittent in remote areas, especially those prone to bad weather such as typhoons. Ideally, the network must be able to provide service locally even with an unstable or non-existent Internet connection. These requirements led the researchers to develop a low-cost 2G GSM cellular base station for community cellular networks (CCNs).

To reduce the capital expenditures for the equipment, the base station was built using off-the-shelf hardware and open-source software. It is able to run on renewable energy sources such as solar power to reduce the reliance of the service on grid electricity. Each CCN has a satellite (very small aperture terminal or VSAT)

Fig. 21.1 A typical installation of a community cellular network cell site piloted in the Philippines

backhaul via which it eventually connects to the broader public telephone network. A typical installation is shown in Fig. 21.1.

Unlike other community network deployments using Wi-Fi as the access technology, 2G GSM cellular technology was chosen because there is still a large 2G subscriber base in the Philippines, especially among low-income and rural residents. GSM is supported by most handsets, even basic feature or "candybar" phones, so most people already owned devices compatible with the network at the time of deployment.

Given the absence of available radio frequency spectrum and regulatory frameworks for last-mile initiatives such as CCNs, legal network operation in GSM frequencies relied on a public-private partnership with the Philippines' leading mobile network operator (MNO), Globe Telecom, for sharing permission to broadcast in their nationally licensed cellular spectrum. Globe also allowed the project to use their SIM cards, phone number allocations, and cloud services which provided interconnection services between the CoCoMoNets network and other telephone networks.

To allow the co-existence of the community cellular networks alongside the mainstream Globe network, the researchers used the CommunityCellularManager (CCM) software stack, a novel IP-based cellular core network that allows multiple separate community networks to be managed (i.e., configured, monitored, and provided with interconnection and billing services) under one technical domain.

The CCM system is divided into two modules: the Client and the Cloud. In this deployment, Globe managed a CCM Cloud instance and provided the researchers at UPD with an account for the project's Client networks. The CCM Cloud handled integration with the Globe network, which provided routing, interconnect, and phone numbers. The CCM Client was installed on the remote base stations. Network installations were then handled independently of Globe by the researchers and community partners.

2.2 Operational Model

The project team partnered with several local institutions and organizations in the deployment sites for network operation. At the grassroots level, local business cooperatives were recruited for day-to-day technical and business operations. Local government units (LGUs) at higher municipal and barangay levels were also engaged, as they had administrative jurisdiction over the deployment areas. Finally, faculty and students at the nearby Aurora State College of Technology (ASCOT) were onboarded for more advanced technical support of the community cellular networks.

The community-based operational model had two aspects: technical and commercial operations. Each aspect employed a three-tiered structure for scoping the roles and responsibilities of the actors. The three tiers, simply referred to as Level 1 (L1), Level 2 (L2), and Level 3 (L3), are detailed in Table 21.1. L1 comprised community partners, L2 comprised cooperative and LGU partners, and L3 comprised the researchers, who acted as the liaison with Globe Telecom (see Fig. 21.4).

For the technical operations, the tiers were defined according to foreseen maintenance, troubleshooting, and repair activities. The simplest and most frequent issues (e.g., power failure) were designed to be resolvable at the community level (L1). This eliminated the need for the research team to travel to the sites all the way from Manila (a full day's journey) for simple checks or repairs, ensuring quicker service restoration.

For the commercial operations, the tiers were defined based on the reach and resources of the relevant actors to carry out the needed business operations. The L1 tier was assigned to local store owners, leveraging their existing infrastructure, capability, and capital to perform retail transactions. A local business cooperative filled the role of L2, using its capacity to coordinate with multiple L1 retailers within its base municipality. The MNO (Globe) filled the role of L3, tasked with provision of SIM cards and wholesale sale of prepaid airtime (also called electronic load or e-load). A revenue-sharing agreement was set up between Globe and the cooperatives, so that revenues could be funneled back to the community to finance the network's operating expenses.

Table 21.1 Technical and commercial operational structure

	Technical	Commercial		
Tier level	Actors	Responsibilities	Actors	Responsibilities
L1	On-ground partners (maintenance officer, security personnel, site leader)	Basic day-to-day upkeep of system Site security Reporting to L2 and L3	Retailers	Sell e-load to subscribers Buy e-load from cooperative Distribute remaining SIM cards to identified subscribers Receive subscribers' concerns
L2	SUC, cooperative, and representatives from LGU	Intermediate troubleshooting and repair tasks beyond L1 capability and resources Coordination between L1 and L3	Cooperative	Sell e-load to retailers Buy wholesale e-load from MNO Pay off maintenance and security personnel
L3	Research team and MNO	Remote monitoring of the network Interfacing between local actors and Manila-based stakeholders	Research team and MNO	Sell wholesale e-load to coop Process revenue share Provide SIM cards

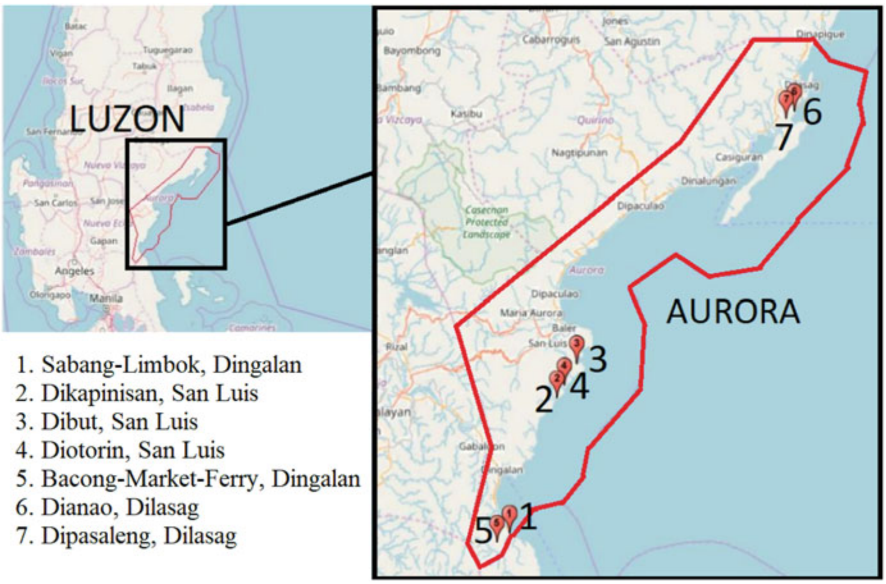

Fig. 21.2 Map of the deployment sites

3 Implementation

3.1 Deployment Context

The CCN deployments, shown in Fig. 21.2, are located in the province of Aurora, in barangays scattered across three municipalities along the Pacific coastline and Sierra Madre mountain range. From Manila, it takes 8 to 10 hours of land travel to reach Baler, the provincial capital. From Baler, several hours' travel by sea or unpaved roads is required to reach these remote and isolated coastal communities, a trip sometimes made hazardous or impossible by seasonal typhoons. Community members mainly depend on fishing and farming for income and sustenance. A few locals earn their living by reselling retail goods brought from the town centers to their respective communities. Owing to their geographic location, these sites do not have access to terrestrial radio and television broadcasts. Prior to the commencement

Fig. 21.3 SIM card distribution during community network launch event

Table 21.2 Final list of sites and their status as of March 2020

Site no.	Treatment site	Municipality	Population estimate (as of 2016)	Date launched	Status as of Feb 2020
1	Sabang-Limbok	Dingalan	450	Sept. 13, 2017	Inactive
2	Dikapinisan	San Luis	2177	Oct. 25, 2017	Active (Wi-Fi)
3	Dibut	San Luis	1032	Feb. 1, 2018	Active (Wi-Fi)
4	Diotorin	San Luis	578	May 30, 2018	Active (Wi-Fi)
5	Bacong-Market-Ferry	Dingalan	500	Aug. 29, 2018	Inactive
6	Dianao	Dilasag	300	Oct. 17, 2018	Inactive
7	Dipasaleng	Dilasag	500	Jan. 25, 2019	Inactive

of the CCN deployments, they were beyond the reach of cellular coverage; locals would need to travel several hours to use cellular services like calls, SMS, and data.

The project installed seven community cellular networks in Aurora from September 2017 to January 2019. These sites were randomly selected from a pool of 14 candidate sites as part of a randomized controlled trial (RCT) impact assessment study.

Prior to the networks' installation, all candidate sites underwent a household-level baseline survey in December 2016. The baseline survey involved three parts: (1) a household survey, (2) a listing of all adults 15 years or older, and (3) a one-on-one adult survey. The household survey queried household demographic composition, asset ownership, and economic activity. The core adult survey asked about social networks and included a travel diary. Across the 7 CCN sites, 1131 households were interviewed, and we listed 3057 adults (Keleher et al., 2020).

The survey data was used as input to a pairwise matching procedure as described in Bruhn and McKenzie (2009). First, potential cell tower locations were sorted into pairs that were as similar as possible along observable characteristics, and then one location within each pair was randomly selected to receive a cell tower in the first wave (treatment) of deployments. The other would receive a cell tower in the second wave (control). Specifically, pairs were formed so as to minimize the Mahalanobis distance between the values of all selected characteristics within pairs, using an optimal greedy algorithm. The research design required the CCNs to be deployed in a specific order.[1] Table 21.2 shows the final list of pilot sites. Several months after a site's network was launched, a household-level randomized experiment was performed on promotional pricing such as free credits and discounted rates.

Finally, from May and September 2019, surveyors returned to all 14 candidate sites to conduct an end line survey to measure changes after the network installations. Surveyors administered the same household and adult surveys, prioritizing interviews with the same individuals as in the baseline.

[1] Throughout the chapter, sites may be referred to by either their site number or name.

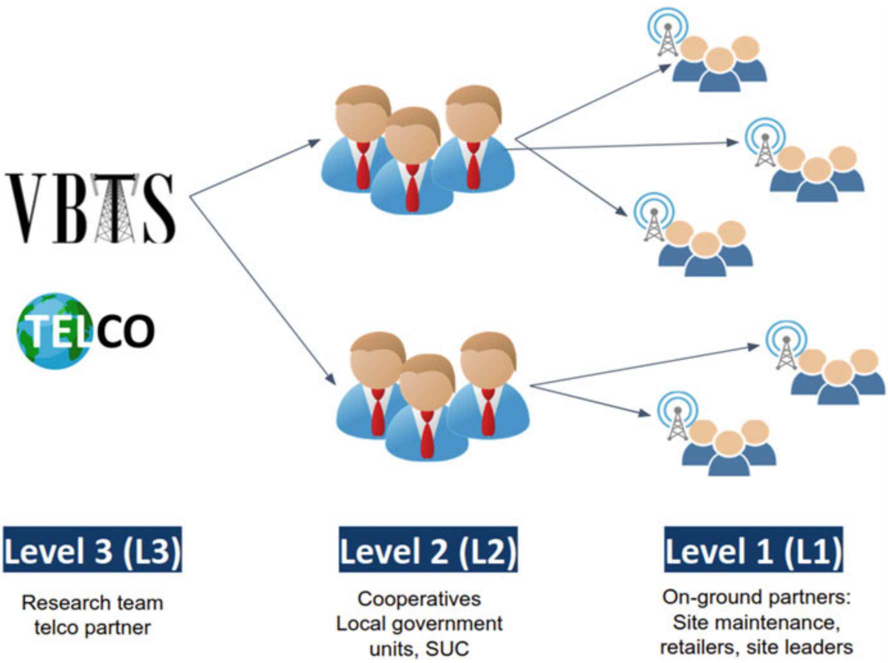

Fig. 21.4 An illustration of the operational tiers

As part of the RCT study, SIM card distribution was tightly controlled as shown in Fig. 21.3. While SIM cards were given for free, only eligible individuals could receive them. Eligible individuals were defined to be 15 years old and above, residing in the community for at least 6 months at the time of site launch. The impact evaluation team had initially wanted to limit SIM cards only to residents of the barangay. However, upon request, exemptions were given to civil workers such as public school teachers and soldiers, as they were often assigned from other municipalities.

The network was dubbed "VBTS (Village Base Transceiver Station) Konekt Barangay" and branded separately to differentiate it from the mainstream Globe network. Pricing for the network services was already set by Globe Telecom and the national regulator. As the CCN was categorized as an experimental network, the per-minute or per-SMS service rates were lower than those of the mainstream network. Any price changes (such as the time-limited promotional pricing or "promos") were to be approved by Globe first and then by the national regulator. Service rates are shown in Table 21.3.

Table 21.3 Table of service rates

Traffic stream	Tariff (in PHP)	Unit
Calls from a VBTS barangay number to another VBTS barangay number	1.00	Per min
Calls from a VBTS barangay number to a regular Globe number	3.00	Per min
Calls from a VBTS barangay number to a non-Globe/VBTS barangay number	5.50	Per min
Call from a VBTS barangay number to an NDD number	5.50	Per min
Text/SMS from a VBTS barangay number to another VBTS barangay number	0.25	Per SMS
Text/SMS from a VBTS barangay number to a regular Globe number	0.50	Per SMS
Text/SMS from a VBTS barangay number to a non-Globe/VBTS barangay number	1.00	Per SMS

3.2 Implementation Challenges

Aside from developing the technical intervention, the project required coordination and work with a wide variety of stakeholders. These included a national mobile network operator (Globe), the national regulatory agency (National Telecommunications Commission – NTC), local government units, research collaborators in the academe, local cooperatives, and network end users within the remote communities. A large amount of time and resources were invested to establish the necessary partnerships and agreements with these stakeholders.

3.3 Spectrum Negotiations

With the core technical pieces in place, the researchers quickly discovered that starting these community cellular networks was not as straightforward as they had originally envisioned. The Philippines does not have a dedicated spectrum policy for last-mile service delivery, and the current regulatory framework forces small operators to adapt to the model used for national telecoms and other large organizations. MNOs are given licenses that span the whole country, even in areas where they are not providing service. Furthermore, current regulations on radio equipment use, SIM card production, and interconnect limit these activities to only MNOs.

There was no path for community networks to apply for their own licenses. In response, the project team first attempted to acquire a license exemption from the national regulator, the NTC. However, the regulatory officers advised the researchers to instead reach out to any of the current license holders and ask if they would allow co-use of frequencies under their respective licenses. The NTC would allow the project, provided an official agreement was acquired with a current licensee.

The researchers sent out proposals to the major Philippine MNOs, to which Globe Telecom responded.

The long negotiation process with Globe took more than 2 years to close.[2] The project worked its way internally through various departments, explaining how different components of the project would pan out upon deployment. The research team also had to reassure Globe that the project would shoulder the CCN's capital and operational expenses. Eventually, the project was taken under Globe's corporate social responsibility arm and was granted approval to use Globe's spectrum for an initial 1-year pilot period. One of the risks the project took on due to this spectrum arrangement was that the CCNs' operation was critically dependent on Globe's continued support.

3.4 Stakeholder Needs and Interests

Over the course of discussions and consultations between the researchers, Globe, and LGUs, we determined that local community partners would be needed to handle the day-to-day operations, management, and first-level maintenance for the CCN installations. The researchers initially wanted to recruit only local organizations based in the same communities as the installations, but were not always able to find organizations that fit these criteria. We enlisted the help of the LGU to nominate cooperatives and organizations and ended up with cooperatives not based in any of the target communities, but local to the municipality. Table 21.4 describes the partnership setup per municipality.

Moreover, the researchers wanted to maximize community involvement to create an operational model for the network that was as close as possible to the ideals of community networking yet that would also satisfy the other partners' requirements. While the team had past deployment experience on which to base the operational model, Globe's stipulations had to be accommodated. Globe preferred to have a single point of contact, rather than dealing with many independent communities. Its existing trade and distribution processes also relied heavily on partners having easy access to financial institutions such as banks and means of electronic communications such as email.

The cooperatives were primarily worried about the capital and potential financial liability that this venture could bring should the project not become sustainable. They also recognized that they would need to visit the retailers at the sites often, which might become inconvenient or infeasible due to the danger of travel in bad weather. They were skeptical about the business viability, as some of the treatment sites were very small in population. These were all valid concerns, especially as these deployments would be a test of the CCN model. However, they were convinced to participate primarily by the 80% revenue share they would eventually

[2] https://www.up.edu.ph/index.php/up-globe-sign-moa-for-village-base-station-project/

Table 21.4 Cooperative setup per municipality

Municipality and sites covered	Partnership setup
Dingalan, Aurora Site 1: Sabang-Limbok Site 5: Bacong-Market-Ferry	The nominated cooperative is the Paltic Mangingisdang Nagkakaisa Producers Cooperative (PAMANA). However, PAMANA is not based in the same barangay as the site installations, so another local group named the Samahan ng Mangingisda ng Sitio Limbok at Sabang (SAMAHAN) was engaged. These two groups are already acquainted with each other and have already worked together for a previous government project. SAMAHAN performed the day-to-day operations and maintenance duties for the sites, while PAMANA is in charge of the distribution of load to the on-ground retailers
San Luis, Aurora Site 2: Dikapinisan Site 3: Dibut Site 4: Diotorin	The nominated cooperative is the Dibayabay Primary Multipurpose Cooperative (DPMC). The cooperative is based in Barangay Dibayabay, which currently has no VBTS installation, but has extended membership in Sitio Diotorin, one of the current VBTS sites. The DPMC performs the distribution of load to the on-ground retailers, as well as other functions
Dilasag, Aurora Site 6: Dianao Site 7: Dipasaleng	The nominated cooperative is the Dilasag Municipal Employees Credit Cooperative (DMECC), which is based in the town proper. The sites are 20–30 min away. DMECC has members residing in sites 6 and 7

receive from the network's gross revenues. As L2 actors, the cooperatives would also receive a discount on the wholesale e-load purchases from Globe as well as their 80% share. Finally, the project team assured the cooperative that all initial investments for the infrastructure were funded by the project.

3.5 Unexpected Changes in the Field

While the spectrum negotiations were taking place, the deployment team from UPD had been visiting and surveying potential sites where little to no cellular coverage existed. The team had set criteria for selecting pilot sites for CCN deployments. A primary consideration was for a village to be outside existing cellular coverage. Initially, five isolated coastal barangays in San Luis, Aurora, were selected as deployment sites. However, the introduction of the RCT study required additional sites to meet the minimum requirement for the matched pairs design (at least 14 sites). Hence, the search was extended to include nearby coastal communities in the town of Dingalan.

The initial site listing was vetted by Globe to ensure that they were indeed excluded on their existing coverage map. At the time, the Dingalan sites were on the fringes of existing cellular coverage. This meant that coverage was not present in the village, but residents had identified spots several kilometers outside the village where they could acquire a signal by walking.

The data gathered from the site surveys were then passed to the impact assessment study team for evaluation. The researchers then generated a final listing of seven treatment sites, with the research design necessitating that the CCNs had to be installed and deployed in a specific order. As a result of this process, the sites were primarily selected according to RCT requirements and not for business viability. Some of the target sites were very small in population and had been identified from the onset as having potential difficulty with generating enough revenue to cover recurring costs without external support.

Over the course of site preparations (mid-2017), two of the treatment sites in Dingalan needed to be relocated due to unforeseen security threats from military insurgent groups in the area. This forced the research team to abort some of the initially selected sites, and the deployment team had to scout other nearby areas for candidate locations, prompting a re-evaluation of the control-treatment pairs. The project team then had to forge new partnerships with local stakeholders in these locations.

Once the treatment sites were identified, the next step was to secure a small lot (7 m × 7 m) in each site where the CCN tower and equipment shelter would be built. If possible, the project team preferred to have the CCNs erected on government land, as the project already had partnerships with the LGUs that had assisted in expediting site clearances and other permits.

However, the project team had a hard time acquiring land for the sites in Dingalan, as a private corporation, Green Square Properties, claimed ownership over almost the whole municipality. The team initially attempted to seek permission with this private entity, but the company wanted lease payments in exchange. As we could not guarantee that income would be generated, the negotiations with them failed. The team tried by all possible means, including leveraging the land-use agreement that the Dingalan LGU had with Green Square. The negotiations for land use took a considerable amount of time and was further complicated when sites had to be re-randomized. In the end, the team ended up making informal arrangements with private homeowners in the area.

In subsequent visits to Dingalan, the researchers observed that network coverage from mainstream networks had improved since these locations were first assessed. By mid-2018, mainstream network coverage had expanded so that residents could now utilize them in the comfort of their homes. With this change, residents in Dingalan preferred to use the mainstream networks over the community network since residents perceived them as more reliable and affordable, and they offered additional services such as mobile data and promos for “unlimited” usage. The community network could not compete with the incumbent MNOs. While the coverage expansion was detrimental to the survival of the community network, we acknowledge that it ultimately brought benefits to the community.

4 Evaluation

4.1 Subscription and Usage

At their peak, the CCNs had about 2000 subscribers, equivalent to about 90% of the total eligible population across all sites. We believe the high adoption rate can be attributed to the RCT study giving away SIM cards for free. About 40% of subscribers topped up monthly, spending $1.20 per month. Monthly ARPU (average revenue per user) across all sites was around $0.60. Voice calls dominated the overall traffic, with 15 times more inbound call minutes to subscribers on the network than outbound call minutes. On the other hand, subscribers made three times more outbound text messages compared to inbound text messages. This was indicative of a "call-me" behavior, since subscribers were only charged for user-initiated calls or SMS.

4.2 Technical Operations

Stable network performance is crucial to smooth network operations. While the technical team took measures to make the systems robust to rural conditions, the system is still not fault-proof and occasionally encounters technical issues that disrupt service. During the first few months of operation, subscribers considered such service disruptions and downtime acceptable, from the viewpoint of their prior condition where they had no network coverage at all. However, their service expectations and attitudes changed throughout the course of the project. Subscribers started to expect continuous and reliable operation similar to their experience with mainstream cellular networks in Baler.

The deployed systems had occasional hardware issues, which were most frequently power-related. Most power failures were due to low battery charge during the rainy season (May–November). The system's battery bank was designed to be sufficient for 3 days of autonomous operation, but limited sun hours prolonged the duration to fully charge the battery bank. The technical team initially tried to operate the network 24/7, but this became very challenging once the rainy season arrived. In response, the researchers and community maintenance staff agreed to limit the operational hours from 5 AM to 10 PM. Initially, the staff had to manually turn off the system, but it turned out that sometimes they forgot to perform the shutdown routine or found it too inconvenient. To resolve this, a digital timer switch was installed that turned the system off and on at the specified times. The switch could be manually overridden by the local staff, in case the community needed extended hours or for emergencies.

Another common cause of network failure was broken inverters, which required replacement hardware to be shipped from L3 or L2. For worst-case scenarios, the researchers were pleased to discover instances where the local maintenance staff had taken the initiative and coordinated with the barangay council to allow powering the CCN hardware using the barangay's electric grid connection or emergency power systems.

In the event that a network hardware component fails, it can take weeks to get replaced or repaired. Specialized equipment is almost impossible to procure in Baler and most often needs to be supplied from Manila. Anticipating this, the project team practiced providing backup inventory for commonly failing components. To expedite replacement of commonly available off-the-shelf hardware, an arrangement was made with the partner LGUs so that they would supply the needed hardware and ship it off to the sites. The on-ground personnel at the site would then perform the hardware installation.

4.3 Commercial Operations

The local business cooperatives were responsible for e-load replenishment, a two-part process that required them to (a) remit payments to the MNO through banks or remittance centers and (b) travel to the sites to provide load to the retailers. Replenishment was challenging primarily because these tasks required personnel travel, which varied in feasibility (e.g., favorable weather conditions and available transportation). Banks and remittance centers were only located in municipal town centers, and the CCN sites were also separated from the cooperative's home base. While e-load transactions can be done electronically, payments and remittances were particularly difficult for cooperatives to receive due to the geographical distances of the sites from the town centers. Payments needed to be remitted regularly for the prescribed commercial model to run smoothly, as cooperatives had a very limited amount of capital to circulate for commercial operations.

As a result of the challenges of travel, some hard-to-reach sites experienced e-load shortages lasting 1–2 weeks, with the worst one lasting for about a month. A straightforward solution was to increase inventory capacity per retailer, also preferred by the cooperative partners as it would require fewer visits for payment collection. However, some retailers expressed an inability to spend larger amounts of capital at a time for more e-load. The retailers and the cooperative were able to work out possible schemes to optimize their process and ease capital requirements. Schemes included setting larger load orders to reduce the frequency of cooperative visits while using a consignment-based structure to reduce capital requirements on retailers. In the "consignment" scheme, the cooperative agreed to transfer the retailer a large amount of e-load for a 50% down payment and 50% balance to be paid on the next collection date.

4.4 Community Response

In general, community buy-in was not that difficult to gain since locals immediately saw the benefits that the project would bring to their respective communities. In informal interviews during the site survey phase, locals highlighted that the network would be useful for emergencies and for contacting loved ones far away. There were a few concerns about radiation and potential negative health effects, but residents were assured that the community base stations transmit at a fraction of the power that typical base stations use. Eventually, the positive benefits of being able to communicate long distance, i.e., make a call without needing to leave their villages, outweighed these concerns.

Though the CCNs were made possible by the partnership with Globe, the researchers wanted to emphasize to the community that this was a separate initiative whose primary purpose was research and not income generation. Specifically, the project team wanted to avoid the risk of insurgents misidentifying the community network as a commercial enterprise and possibly extort "revolutionary taxes" from the project.[3] As a response to frequent queries about the project and to avoid misinformation, the research team held town hall meetings prior to and during the CCN's inauguration and formal launch.

The network launch was conducted as a whole community event where the team had a chance to formally introduce the project and explain the details of the research and network operation. The team explained the capabilities and limitations of the system, tariff rates, and information about future promotions. As an experimental network, the VBTS-CoCoMoNets network could be expected to suffer downtime or outages and would not guarantee the same grade of service as mainstream cellular networks. This and other capacity limitations were communicated clearly to all stakeholders, especially to subscribers prior to their sign-up. The event was also an opportunity to address questions and concerns from the community, which included the privacy of their communications, potential health effects of radiation from CCN towers, value-added services such as mobile Internet, and other comparisons of the CCN to mainstream networks.

Subscribers' appreciation of the project depended highly on their distance to existing coverage and the effort required to reach it. The communities of San Luis, Aurora (including Dikapinisan, Dibut, and Diotorin), who are extremely geographically isolated from the rest of the world, were highly appreciative of the community network even though the service offerings were not perfect. Network adoption was also highest in San Luis.

Resistance to the project was most salient in the Dingalan sites. Some community members outspokenly mentioned that VBTS-CoCoMoNets did not have a positive impact on them at all, as it allegedly did not keep its promise of improving mobile reception, and actually weakened the scant signal of the networks they

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[3] Philippine Institute for Development Studies. 2018. "The telco duopoly has become the CPP-NPA's biggest funder" https://pids.gov.ph/pids-in-the-news/2247

had been using prior to the CCN's installation. To make matters worse, the delegated maintenance personnel took a job elsewhere, leaving no one to maintain the equipment. Maintenance and repair had to originate from Manila, making the upkeep of the site much more difficult. The team made several attempts to explain the situation to the community, but the subscribers had lost interest. Due to the dissatisfaction, the team received requests from community members to pull out the equipment, as they did not want liability in the case of theft or damage. Unfortunately, they could not act on the pullout request until the end line survey was completed.

4.5 Personnel Retention

Personnel retention has remained a challenge for CCNs, as delegated personnel find better opportunities beyond their village, limiting their long-term participation. In the designation of tasks, the project team had initially hoped that the required effort and frequency of maintenance (e.g., checking battery voltage daily) would be of little consequence to the personnel everyday routines. However, keeping the L1 and even L2 presence failed in several sites, severely affecting operations and sustainability. In sites with low network traffic and adoption, L1 personnel understandably did not exhibit enthusiasm in fulfilling their duties, as perhaps the subscribers' behavior indicated the CCN's lack of value to them. L1's failure to perform maintenance may have led to further degradation of the service, so that disappointed subscribers returned to their old usage of the mainstream network if available.

The researchers looked deeper into the reasons behind L1 absence and found the following: (a) insufficient compensation and (b) unappreciation of the network's value. Although L1 personnel received an allowance from the LGU or cooperative, they often opted to venture to more rewarding livelihoods for higher compensation. Some allocated more of their time to their fishing or farming activities, while some accepted better jobs outside their community. This tendency to relocate to "greener pastures" for work echoes the overseas Filipino worker (OFW) phenomenon, wherein Filipinos resort to opportunities in more developed countries due to the unavailability of local high-paying jobs. For the context of the project's CCN sites, this translates to migration to more urban areas. The researchers accept the L1 personnel standpoint, as they need to provide for their families. While these migrations are often not permanent, with workers shuffling intermittently between their hometowns and Baler, unavoidable gaps are created when those left behind lack the knowledge to maintain the network. While there is certainly promise and value in providing training to produce local expertise, this training must be consistently available and repeated to be effective. Issues related to personnel turnover can be expected to continue until the community as a whole becomes more technically savvy.

Fig. 21.5 System diagram created by L1 personnel

In one case of L1 absence, the project team was fortunate enough to have a local resident step up to understand the system and take over operations. The formerly untrained resident, with a high school/early college level background in electrical principles, received cursory instructions from the former personnel when he left for work in Baler and took up his functions. He was in charge of the system's upkeep for several weeks before receiving official training from the project team, performing well on his own through self-study of the reference operational manuals and deployed equipment layout. A diagram from the manuals with his own drawing and labels, produced before training, is shown in Fig. 21.5.

4.6 Trust and Community Relations

Forming partnerships and trust with the communities required a tremendous amount of effort and time. The project encountered instances where negotiations took much longer to close than expected, causing delays in the installation and deployment timelines. The team also wanted to ensure participation of local partners and give them the opportunity to exercise their decision-making rights. Moreover, local politics and leadership changes interrupted the continuity of community relationships that had taken a long time to build. In some cases, the project had to re-introduce itself to new local leaders after a new administration was elected. In Philippine politics, it is common to replace or reshuffle all staff when a new administration takes office, so the team had to re-establish connections and re-identify liaisons or L2 personnel for the project.

Despite the difficulties, gaining and maintaining trust with local stakeholders is highly important, as it will influence an intervention's ultimate value and impact for the community. A sense of distrust, as arose in Dingalan, meant that the community would never use and appreciate the network. Building trust requires researchers to spend significant time with the communities and try to understand their way of life. While most of the researchers were Filipinos and understood the local context, they were still living in Manila. Unfortunately, the difficulty of travel and the RCT requirement to minimize survey/response bias limited the researchers' ability to maximize their presence in the communities.

5 Adaptation

By September 2019, four CCN sites had been terminated due to non-performance. They were Site 1 (Sabang-Limbok), Site 5 (Bacong-Market-Ferry), Site 6 (Dianao), and Site 7 (Dipasaleng). "Non-performance" in these cases referred to a lack of subscriber activity, lack of L1 maintenance support, and lack of cooperative business support. While the research team strove to keep these sites running, for example, by performing L1 repairs, replacing any defunct equipment, or initiating pricing promos, the lack of interest from stakeholders signaled that the intervention was not useful for these sites.

In November 2019, a contact at Globe notified the researchers that Globe would be terminating their own parallel set of small-scale cellular deployments based on the same CCM software stack. This was due to various technical and business reasons including hardware vendor problems, target revenues not being met, and lack of support from Facebook, another peripherally involved partner adopting the CCM software. Corporate supports for the existing VBTS-CoCoMoNets sites were bundled with this initiative, and thus they would also be terminated.

With this news, the project team decided to install community Wi-Fi networks alongside the existing 2G cellular networks. Although this intervention was beyond the scope of the current project, the researchers felt the need to provide an alternative for communities that had become reliant on CCN services. Both networks operated in parallel until March 2020, when the 2G networks were taken offline.

Several community consultations were held in the remaining sites of Dikapinisan, Diotorin, and Dibut to discuss the status and future of the project. Inputs from the communities were gathered regarding operation beyond the project period. The main concern for these sites' sustainability was the high cost of the satellite backhaul. Two main proposals surfaced from these discussions. The first was to let the network be free and open for anyone to use, the catch being that the service would eventually end once the VSAT contract paid for by the project ended, if no subsidies were acquired from the local government. The second was to accumulate funds for the monthly recurring costs through sales of Wi-Fi voucher codes to community members wishing to access the Internet. Two out of the three communities (Dikapinisan and Dibut) decided right away to adopt the management of the Wi-Fi network. They would sell voucher codes for Wi-Fi Internet access for PHP 10/h. Sales would be accumulated to pay for the VSAT backhaul starting in August 2020.

Community reception of the Wi-Fi service has been mixed. Some are happy about the introduction of the Internet to their communities, as they had been longing to use the Internet for Facebook, research, or other purposes. Dikapinisan, being the most populous and urban of the three communities, has received the Wi-Fi service very well; residents largely have a prior understanding about what Wi-Fi is and how it can be used. However, some feature phone users were dismayed because their phones do not have Wi-Fi capability, or they still find voice and text easier to use over video calls and chat. Wi-Fi also has shorter propagation characteristics compared to cellular 2G, meaning the coverage area of the community network is now smaller. Community members who were not covered by the Wi-Fi signal coverage would have to walk or congregate near the community access point. Finally, the termination of 2G service has disenfranchised some community members who do not have the capacity to upgrade to Wi-Fi-enabled devices. The situation has been difficult for the research team to accept, but we have had to acknowledge our own limited capacity as well.

In spite of this outcome, efforts initiated by the CoCoMoNets project are being continued through other research initiatives. Researchers from UPD and the Department of Science and Technology Advanced Science and Technology – Institute (DOST-ASTI) saw an opportunity with the planned digital TV migration and proposed the opening of the 600 MHz spectrum for use of community cellular networks, and thereby addressing the challenges encountered by the CoCoMoNets project revolving around spectrum usage. To support this proposition, researchers from DOST-ASTI have developed an LTE base station prototype operating at 600 MHz (Hilario et al., 2020). Recently, the ongoing COVID-19 pandemic has brought again to spotlight the long-standing problem of last-mile connectivity access in the Philippines. As part of the government response to address the connectivity gap, the Philippine's Department of Science and Technology announced that it is planning to build community cellular networks in remote areas across the country to provide Internet connectivity that could aid in distance learning.[4] This pronouncement is a positive step forward as community networks are being

[4] Jaehwa Bernardo. September 2020. ABS-CBN News. "DOST plans to build community-based cellular networks in remote areas" https://news.abs-cbn.com/news/09/29/20/dost-plans-to-build-community-based-cellular-networks-in-remote-areas

acknowledged as a solution to last-mile access. Moreover, the government's adoption of community networks is expected to bring the necessary support for crafting responsive regulatory policies and additional spectrum reform that will help narrow the digital gap in the country and resolve some of the issues surfaced through this study.

6 Discussion: Open Challenges

The geographical remoteness of the sites, while important for the networks' business success, resulted in a number of setbacks in creating a feasible trade and distribution process. The sites are far away from formal financial institutions like banks and remittance centers; travel time and difficulty reaching the sites also pose ongoing dangers to local intermediaries.

MNOs operating at massive scale are not well suited to using iterative or rapid design processes, which may be crucial when working with new technologies or marginalized populations to make interventions appropriate for adoption. For example, during negotiations with Globe, it was agreed that co-ops would receive 80% of the revenue share, which would be used to cover operating costs of the site beyond the project duration. However, the co-ops' receipt of their share was delayed, as Globe later required them to enter into separate contracts directly with Globe. These contracts took almost another 2 years to get approved. Moreover, executing the revenue share in practice was a longer process than initially expected. Globe's revenue share disbursement was not completed until July 2020.

While our counterparts at Globe were committed and worked hard to complete the disbursement, most of the delays were due to procedural precedents in a massive organization attuned to working with other similarly large enterprises. The project team recognized the administrative challenges and potential concerns that arose from this delay, so the team constantly kept lines of communications open for coordination between Globe and the cooperative. Unfortunately, the delays broke the projected operational model, as it was assumed that cooperatives would be able to tap into this revenue for their operational expenses or for additional capital for e-load distribution. To help alleviate their concerns during this unfortunate development, persistent and continuous communication with both the cooperatives and Globe was important and necessary. The team also extended assistance to both parties to expedite completion of the requirements (e.g., getting required documentation or assisting cooperatives in digital account setup).

7 Summary and Conclusion

Despite all the operational challenges, the researchers still believe that community networks will play an important role in rural communications, especially when market forces fail to deliver service in last-mile areas. However, CCNs will continue to face challenges without supportive and enabling environments, requiring coordination and commitment from government, academia, industry, and community. A systematic review of community network strategy by policy makers and stakeholders will be required to allow CCNs to flourish. Finally, meaningful and sustainable impact requires more than a 2-year pilot project. To achieve larger-scale, more holistic development impacts in rural areas, we will need long-term roadmaps for rural development with respect to both physical infrastructure and human resources.

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