Abstract

Community networking is an approach to providing communications access in unserved and underserved areas where market forces have failed to deliver service due to high risk of investment and limited returns. This situation persists in much of the Philippines where, with just under 70% mobile phone penetration, unserved communities have limited options to gain access to the benefits of connectivity.

This chapter describes the CoCoMoNets Project (Connecting Communities through Mobile Networks) implemented by researchers at the University of the Philippines Diliman (UPD) and international research partners, which aimed to deliver basic mobile telephony to a small number of remote rural barangays[1] in the Philippines through community cellular networks. The technology core of CoCoMoNets is a low-power, low-cost 2G GSM base station that enables voice calls and SMS at a fraction of the capital and recurring expenses of traditional cellular network deployments. The system uses off-grid power sources such as solar, and uses VSAT (Very Small Aperture Terminal) backhaul to connect subscribers to the broader public telephone network.

Aside from developing the technical intervention, implementing this project required working with a wide variety of stakeholders, including a national mobile network operator, the national regulatory agency, local government units, research collaborators in the academe, local cooperatives, and network end-users within the remote communities. In doing so, we encountered a multitude of challenges including radio spectrum use, tower licensing, remoteness, maintenance and repair difficulties, local politics, and community relations.

We document our experiences and challenges in testing this model in the real world. After almost two years of operation, we reflect on our learnings to contribute to the development of future approaches in delivering sustainable last-mile communication access.

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. Unfortunately, many people still live beyond the reach of cellular coverage and including in the Philippines, especially in remote rural regions of the country. One of the reasons is that existing mobile network operators (MNOs) had been unwilling to make the large investment required to establish traditional cellular infrastructure in areas where the potential number of users would not be not enough to cover the capital and operational costs. Our solution became to utilize cellular infrastructure that incurs much lower costs so that deployment in remote rural areas becomes economically viable.

The CoCoMoNets Project (Connecting Communities through Mobile Networks) implemented by researchers at the University of the Philippines Diliman (UPD) and international research partners, aimed to deliver basic mobile

[1] The *barangay* is the smallest political unit in the Philippines. It is abbreviated as Brgy.

telephony, through **Community Cellular Networks** or **CCNs**, to a small number of remote barangays in the Philippines. 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.[2] These initiatives involve local community members and community structures in the deployment, operations, management and ownership of the network.[3]

Building such infrastructure requires careful consideration of the needs and requirements unique to rural areas. First, many remote areas in the Philippines do not have access to reliable grid electricity. As such, the network's power consumption must be low enough to be powered by renewable energy sources. Moreover, backhaul would be likely expensive and intermittent in these areas. Hence, each network node must be able to provide standalone service even with an intermittent or non-existent connection to the Internet. Another key design goal was to provide basic primitives for network management as an independent telecommunications firm, enabling local entrepreneurs to emerge as new entrants in rural areas.

These requirements led us to the development of the Village Base Station (VBTS): a low-cost, low-power 2G GSM base station, refer to Figure 1, that enables voice calls and SMS at a fraction of the capital and recurring expenses of traditional cellular networks. The CCNs are powered using renewable energy sources such as solar power, equipped with solar panels and a battery bank. Each CCN has a VSAT backhaul which eventually connects it to the broader public telephone network. The software for our CCNs is based on the Community Cellular Manager[4] (CCM) stack, a novel open-source, IP-based cellular core solution for operating CCNs at scale within the existing telecom ecosystem.[5] Unlike community network deployments that have used WiFi as the access technology, GSM was chosen because there is still a large 2G subscriber base in the Philippines. GSM is supported by most handsets, even basic feature/candybar phones, which meant that more people already owned devices compatible with the network.

In this chapter, we document our experiences and challenges as we attempted to pilot community cellular networks in the Philippines from 2015 to 2019. Despite initial successes, we encountered barriers to continued operation which led the project team to ultimately shut down sites or pivot to WiFi Internet access networks. We reflect on our learnings, which we hope will contribute to the development of future approaches to delivering sustainable last-mile communication access. We first give an overview of the project in Section II. In Section III, we narrate the challenges that we encountered prior to the CCN deployments. We then follow this with a discussion of the <insert relevant content>

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[2] Steve Song, "Policy Brief: Spectrum Approaches for Community Networks," Internet Society, Tech. Rep., Oct. 2017. [Online]. Available: https://www.internetsociety.org/wp-content/uploads/2017/10/Spectrum-Approaches-for-Community-Networks_20171010.pdf

[3] N. Bidwell and M. Jensen, "Bottom-up Connectivity Strategies: Community-led small-scale telecommunication infrastructure in the global South," Association for Progressive Communications, , Tech. Rep. , 2019.

[4] https://github.com/co-cell

[5] S. Hasan, M. Barela, M. Johnson, E. Brewer and K. Heimerl. (2019). Scaling community cellular networks with community cellular manager. Proceedings of the 16th USENIX Conference on Networked Systems Design and Implementation. Boston, MA, USA

2. Implementation Context

Project Overview

Our conceptualization of community cellular networks began in 2012 with an initial trial deployment in Papua, Indonesia by the TIER (Technology and Infrastructure for Emerging Regions) research group at the University of California Berkeley (UCB) in the United States. In 2013, researchers from UCB and UP wanted to test the concept of community cellular networks and demonstrate similar results in the Philippine context. Moreover, the researchers wanted to augment the networks with local services supporting the growth and flourishing of these rural communities. The VBTS-CoCoMoNets project was born out of this collaboration, with funding primarily coming from the Philippines' Commission on Higher Education. However, due to procedural delays,[6] the project did not take off until 2015.

The project team was initially composed of primarily technologists and engineering researchers from UP and UCB. Later on, it was deemed important to provide evidence for the impact of the communication access. As such, the team expanded to include social scientists and economists from the UPD, UC Berkeley and UC Davis. The evaluation centered on the impact of cellular connectivity in our partner communities, specifically across gender and social networks, through the use of a longitudinal randomized control trial (RCT) and participatory qualitative research. In 2017, researchers from the University of Washington collaborated with the project to study rural repair and maintenance.

Given the absence of regulatory support for initiatives such as CCNs, the project relied on a public-private partnership with the leading mobile network operator (MNO) in the Philippines, Globe Telecom, for sharing permission to broadcast in their nationally-licensed cellular spectrum band. Globe also allowed us to use their SIMs, phone number allocations, and cloud services which provided the interconnect from the VBTS network to other phone networks.

We partnered with several local institutions and organizations in the deployment sites. At the grassroots level, we engaged with local cooperatives for the day-to-day operations of the community cellular networks. Local government units at the municipal and barangay levels were also engaged as they had administrative jurisdiction over our deployment areas. Finally, we onboarded faculty and students at the Aurora State College of Technology for higher-level technical support of the community cellular networks.

Deployments

Context

Our CCN deployments are located in the province of Aurora, Philippines. The sites are located in barangays scattered across three municipalities, situated along the Pacific coastline and Sierra Madre mountain range.

[6] GMA News Online. "CHED: PCARI not anomalous, will drive science research" https://www.gmanetwork.com/news/scitech/science/329941/ched-pcari-not-anomalous-will-drive-science-research/story/

From Manila, it takes 8 to 10 hours of land travel to reach Baler, the provincial capital of Aurora. From Baler, several hours of travel by sea or unpaved roads are 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 of our 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.

Randomized Controlled Trial

From September 2017 to January 2019, the project installed 7 community cellular networks in Aurora (refer to Figure 2). These sites were randomly selected from a pool of 14 candidates as part of the randomized control trial (RCT) study for impact assessment. All candidate sites underwent a household-level baseline survey, conducted in December 2016. This effort involved conducting two 1-hour interviews with roughly 1,500 unique individuals in 14 different barangays. Survey data was used as input to a pairwise matching procedure. First, all 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). The research design necessitated that the CCNs had to be installed and deployed in a specific order. Table 1 shows the final list of pilot sites.[7]

Network Enrollment

As part of the RCT study, SIM card distribution was tightly controlled. While the SIM cards were given for free, only eligible individuals can only avail of the SIM cards. Eligible individuals were defined to be those 15 years old and above, and were residing in the community for at least 6 months at the time of site launch. Initially, the impact evaluation team 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.

Pricing

The network was dubbed "VBTS 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 regulator. Since we were running an experimental network, the per minute or per SMS service rates were much lower than the mainstream network. Pricing changes (including time-limited promotional pricing or "promos,") had to be approved by Globe first, and then by the national regulator. Refer to Table 2.

Subscription and Usage

At its peak, the CCN network had about 2,000 subscribers, equivalent to about 90% of the total eligible population across all sites. The high adoption rate can be attributed to the RCT study, as SIM cards were given for free. About 40% of the subscribers topped-up monthly, spending $1.20 per month. Monthly ARPU across all

[7] Throughout this chapter, we may refer to sites according to their site number or name.

sites was around $0.60. Voice calls dominated the overall traffic, with subscribers taking 15x times more inbound calls minutes than outbound calls minutes. On the other hand, subscribers made 3x 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.

Operational Model

Our 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 L1 (Level 1), L2 (Level 2) and L3 (Level 3), are detailed in Table 3. L1 comprised community partners, L2 comprised cooperative and LGU partners, and L3 comprised the researchers, who acted as the liaison with Globe Telecom.

For the technical operations, the tiers were defined according to the foreseen maintenance, troubleshooting and repair activities. During the formulation of these tiers, we made sure that the most simple, yet frequently occurring issues (i.e. power failure) were resolvable at the community level. Doing so eliminated the need for the research team to travel all the way from Manila for simple checks or repairs, thus 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 business operations. The L1 tier was assigned to local store owners, utilizing their existing infrastructure, capability, and capital to perform retail transactions. The local cooperative filled the role of L2, with its capability to interact with multiple retailers from the sites within its base municipality. The MNO filled the role of L3, tasked with provision of SIM cards and wholesale selling of prepaid airtime (also referred to as electronic load or e-load). A revenue-sharing agreement was set up between the MNO and cooperatives, so that the received revenues could be funnelled back to the community to finance the network’s operational expenses.

3. Implementation Experiences

Aside from developing the technical intervention, the project required working with a wide variety of stakeholders, including a national mobile network operator, the national regulatory agency, 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.

Spectrum Negotiations

With the core technical pieces in place, we quickly discovered that starting these community cellular networks was not as straightforward as we had 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 telcos and other large organizations. MNOs are given licenses that span the whole country,

even in areas where they are not present. Furthermore, current regulations on equipment, SIM card production, and interconnect are limited to MNOs only.

Since there was no room for community networks to apply for their own licenses, the project team first attempted to acquire a license exemption from the national regulator, the National Telecommunications Commission (NTC). However, the regulatory officers advised us to reach out instead 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 our project provided we got an official agreement with a licensee. We sent out proposals to the major Philippine MNOs, to which Globe Telecom responded.

Our long negotiation process with Globe took more than two years to close.[8] We worked our way internally through various departments to explain how different components of the project would pan out upon deployment. Moreover, we 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. Due to this spectrum arrangement, one of the risks we took on was that continued operation of the deployed CCNs was critically dependent on Globe's support.

Stakeholder needs and interests

Over the course of discussions and consultations with Globe, LGU, and the researchers, it was determined that local community partners were needed to handle the day-to-day operations, management, and first-level maintenance for the VBTS installations. We initially wanted organizations based in the same communities where the CCN installations were located. However, we were not 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 who, while local to the municipality, were not based in any of our target communities. Table 4 describes the partnership setup per municipality.

Moreover, the researchers wanted to create an operational model for the network that was as close as possible to the ideals of community networking by maximizing community involvement, yet that would also satisfy the requirements of our other partners. While we had past deployment experience on which to base our model, we also needed to factor in Globe's requirements. Globe Telecom prefered to have a single point of contact, rather than dealing with many communities. Also, its existing trade and distribution processes relied heavily on the assumption that partners had easy access to financial institutions such as banks, and to means for electronic communications such as email.

From the cooperatives' side, they were primarily worried about capital and potential financial burden that this venture could bring, should the project not become sustainable. The cooperatives also recognized that they

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

would need to visit the retailers frequently, which might not be possible due to inconvenience or infeasibility of travel during bad weather. They were skeptical about the business viability, as some of our treatment sites were very small in population. These were all valid concerns, especially as these deployments would be a test of the CCN model. We were able to convince the cooperatives on board primarily through the 80% revenue share that they would eventually receive from the network's gross revenues. As L2 actors, the cooperatives would receive a discount on the wholesale e-load purchases from Globe as well as an 80% share on the net revenues generated by the network. Finally, the project team assured the cooperative that all initial investments for the infrastructure was funded by the project.

Unexpected changes in the field

While the spectrum negotiations were taking place, the deployment team from UP had been visiting and surveying potential sites where little to no cellular coverage existed. The UP team had set criteria for selecting pilot sites for CCN deployments. One 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 to be feasible (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 these 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. As a result, a final listing of 7 treatment sites were generated and the research design necessitated 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 difficulties in generating sufficient 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 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 UP team then had to forge new partnerships with local stakeholders in these locations.

Once the treatment sites were identified by the RCT team, the next step was to secure a small lot (7m x 7m) where the CCN tower and equipment shelter would be built. As much as possible, we 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.

We had a hard time acquiring land for our Dingalan sites, as almost the whole municipality was claimed to be owned by a private corporation. We initially attempted to seek permission with this private entity, but the company wanted lease payments in exchange. As the CCNs could not guarantee that income would be generated, our negotiations with them failed. The team tried by all possible means, including leveraging the land-use agreement that the Dingalan LGU had with this private corporation. 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, we ended up having informal arrangements with private homeowners in the area.

In our subsequent visits in Dingalan, the research team observed that network coverage from mainstream networks had improved since the time we first assessed the location. By mid-2018, coverage from mainstream networks had expanded, which meant they could now utilize these 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. Additionally, they offered additional services such as ``unlimited'' promos and mobile data access. Our network could not compete with the incumbent MNOs. While this change was detrimental to the continued usage of the community network, we acknowledge that it was ultimately beneficial to the community.

Technical Operations

Stable network performance is crucial to smooth network operations. While we took measures to make our systems robust to rural conditions, our 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, speaking from their prior condition where they previously did not have any network coverage. However, service expectations and attitudes changed during the course of the deployments. We observed that subscribers started to expect continuous and reliable operation similar to their experience with mainstream cellular networks in Baler.

Most power-related issues were due to low battery charge during the rainy season. The system's battery bank was designed to be sufficient for three days of autonomous operation, but limited sun-hours prolonged the duration to fully charge the battery bank. We initially tried to operate the network 24/7, but this became particularly challenging once the rainy season arrived. As a response, the researchers and the maintenance staff agreed to limit the operational hours from 5AM to 10AM. For the first few deployments, the staff had to manually turn off the system, but it turned out that sometimes the staff forgot to perform the shutdown routine or found it too inconvenient. To resolve this, we installed a digital timer switch that turned off the system during the specified times. This switch can be manually overridden by the local staff, in case the community needed extended operational 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, we were pleased to discover that were instances where the local maintenance staff took 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 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. Because of this, the project team practiced providing backup inventory for commonly failing components. To expedite replacement of commonly available off-the-shelf hardware, we worked out an arrangement with our partner LGUs so that they would supply the needed hardware and ship them off to the sites, where the on-ground personnel would then perform the actual installation.

Commercial Operations

E-load replenishment was a two-part process that required the cooperative to (a) remit payments to the MNO through banks and remittance centers and (b) to travel to the sites to provide load to the retailers. Replenishment was challenging primarily because these tasks require movement of personnel, which relied heavily on the feasibility of travel (i.e. favorable weather conditions, available transportation). Banks and remittance centers were located in municipal town centers only, while the CCN sites were also separated from the cooperative's home base. While e-load transactions can be done electronically, payments and remittances are particularly difficult for cooperatives to receive due to the geographical distances of the sites from the town centers. For the prescribed commercial model to run smoothly, payments must be remitted regularly, as the cooperative only has a 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 that lasted for 1-2 weeks, with the worst one lasting for about a month. A straightforward solution could be to increase inventory capacity per retailer, also preferred by our cooperative partners as it would require fewer visits for payment collection. However, some retailers expressed an inability to shell out a larger amount of capital for their e-load business. As a compromise, the retailers and the cooperative worked out possible schemes to optimize their process or to ease capital requirements. Schemes included setting larger load orders to reduce the number and frequency of visits, and 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, with 50% outright down payment and 50% balance to be paid on the next collection date.

Community Response

In general, project buy-in was not that difficult to acquire 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, i.e. make a call without the need to leave their own villages, outweighed these concerns. Moreover, though we were in partnership with Globe, we 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.[9]

As a response to these types of queries and to avoid misinformation, the research team held town hall meetings during the inauguration and launch of the CCNs. The network launch was an event where we had a chance to formally introduce the project to the whole community, and explain the details of the research project and the network. The team explained the capabilities and limitations of the system, tariff rates, and information about future promotions. Being an experimental network, it was explained that the VBTS network may suffer downtime or outages and we could 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. Some of the questions revolved about the privacy of their communications, potential health effects of radiation from CCN towers, value added services such as mobile Internet, and other questions comparing the VBTS network to mainstream networks.

Appreciation of the project depended highly on the distance of the sites to existing coverage and the effort required to reach it. In San Luis, Aurora (Dikapinisan, Dibut and Diotorin), where communities were extremely isolated, appreciation of the community network service was high, even though the service offerings of VBTS-CoCoMoNets were not perfect. Adoption of the network was also highest in San Luis.

Resistance to the project was most salient in our Dingalan sites. Some community members outspokenly mentioned that VBTS did not have a significant 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 had been using prior to the CCN's installation. To make matters worse, the delegated maintenance personnel took a job opportunity elsewhere, leaving no one to take over the maintenance of the equipment. Maintenance and repair had to originate from Manila, making the upkeep of the site much more difficult. Several attempts were made to explain the situation to the community, but the research team had lost their interest. Due to the dissatisfaction, we received requests from community members to pull out the equipment, as they do not want liability in the case of equipment theft or damage. Unfortunately, the deployment team cannot act on the pull-out request until the endline survey has been completed.

4. Discussion: Open Challenges

Last-mile Service Delivery

The remoteness of our sites 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 to reach the sites also pose ongoing dangers to local communities.

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

Technical Limitations of Large Telecoms

MNOs operating at massive scale are not well suited to using iterative or rapid design processes. This is problematic when working with new technology or marginalized populations, for whom these techniques can be critical to making interventions appropriate and adoptable.

For example, during negotiations with Globe, it was agreed that the coop would receive 80% of the revenue share, which would be used to cover operating costs of the site beyond the project duration. However, the cooperative's receipt of their share was delayed, as Globe later required the cooperatives to enter into a separate contract directly with Globe. This contract took almost another two years to get approved.

We are looking forward to the completion of Globe's revenue share disbursement to the cooperative, in which the cooperative shall be receiving as a lumped sum. However, while Globe is committed and working hard to enable the disbursement, we have discovered that executing the revenue share in practice is a long process. This is because we are setting a precedent in a big organization whose procedures are attuned to working with other similar large enterprises. We understand the administrative challenges and potential concerns from this delay, so it has been important for us to consistently keep the lines of communications open between Globe, the project team, and the cooperative.

Unfortunately, the delays broke the projected operational model as it was assumed that the cooperative would be able to tap the revenue for their operational expenses, or for additional capital for e-load distribution. To help alleviate the cooperative's concerns during this unfortunate development, persistent and continuous communication with both the cooperative and Globe has been important. The research team has also extended assistance to both parties to expedite completion of some requirements (i.e. getting required documentation, or assisting the cooperative in digital account setup).

Personnel Retention

While there is promise in training and producing local experts, personnel retention has remained a challenge as better opportunities beyond their village limits the long-term participation of delegated personnel. In the designation of tasks, we had initially hoped that the required effort and frequency of maintenance tasks (e.g. checking battery voltage) would be of little consequence to their everyday routines. However, in several sites keeping the L1 and even L2 presence has failed, thus severely affecting operations and sustainability. In sites with low network traffic and adoption, L1 personnel understandably do not exhibit enthusiasm in fulfilling their duties, as perhaps the subscribers' behavior indicates the CCN's lack of value to them. Interpreted differently, L1's absence and failure to perform maintenance duties may have also led to disappointment of the subscribers with the service, so they returned to their old habits and usage of the mainstream network if available.

We looked 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 job opportunities elsewhere. This preference of relocating to "greener pastures" is perhaps analogous to the Overseas Filipino Workers (OFW) phenomenon, where Filipinos resort to opportunities in more developed countries due to the unavailability of high-paying jobs locally. For the VBTS context, this has translated to migration to more urban towns. We acknowledge the L1 personnel's standpoint as they need to provide for their families. While the migration is not permanent (i.e. locals must shuffle between their respective barangays and Baler), unavoidable gaps are created when no one left behind has the knowledge to maintain the network. Moreover, this problem can be expected to continue until the community as a whole becomes more technically savvy.

We were fortunate enough, in one case, to have a local resident step up to understand the system and take over L1 operations. When the original personnel at one site left for work in Baler, an untrained resident with a basic background in electrical principles received cursory instructions from the former personnel and took up his functions. He was in charge of the system's upkeep for several weeks before he received official training, but performed well by studying the reference operational manuals and actual system layout. A diagram from the manuals with his own drawing and labels is displayed in Figure 3.

Trust and Community Relations

Forming partnerships and trust with the community has required a tremendous amount of effort and time investment. We encountered instances where negotiations took much longer to close than expected, which caused delays in our installation and deployment timelines. However, we wanted to ensure our local partners' participation and for them to exercise their decision-making rights. Moreover, continuity of community relationships that took a long time to build was disrupted due to local politics and leadership changes. In some cases the project had to re-introduce itself to new local leaders after a new administration was elected. It is common in Philippine politics to replace or reshuffle staff when a new administration comes in, so the team had to re-establish connections and re-identify liaisons or L2 personnel for the project.

Nevertheless, we emphasize the importance of gaining trust with the local stakeholders, as this influences 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 that researchers spend significant time with the communities and try to understand their way of life. While most of the researchers were Filipinos and understand local contexts, they were still based 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.

2G Shutdown and Pivot

By September 2019, the services of 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 our case 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 replacing

equipment, performing L1 repairs, or initiating pricing promos, the lack of interest from stakeholders signaled that the intervention was not useful for these sites.

In November 2019, our contact person from Globe Telecom notified us that they would be terminating their own set of small-scale cellular deployments based on the 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). Support for 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 a community WiFi network alongside the existing 2G cellular networks. Although this intervention is beyond the scope of the current project, the researchers felt the need to provide an alternative for communities that have become reliant on CCN services. Both networks shall operate in parallel until March 2020, when the 2G networks are 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. Input from the community was 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 and no subsidies were acquired from the local government. The second was to accumulate funds for the monthly recurring costs through sales of WiFi 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 WiFi network. They would sell voucher codes for WiFi Internet access for Php 10/ hour. Sales would be accumulated to pay for the VSAT backhaul starting in August 2020.

Community reception of the WiFi 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 WiFi service very well; residents largely have a prior understanding about what WiFi is and how it can be used. However, some feature phone users were dismayed because their phones do not have WiFi capability, or they still find voice and text easier to use over video calls and chat. WiFi also has shorter propagation characteristics compared to cellular 2G, which meant that the coverage area of the community network is now smaller. Community members who were not covered by the WIFi signal coverage would have to walk or congregate near the community access point. Finally, the termination of 2G service disenfranchised some community members who do not have the capacity to upgrade to WiFi-enabled devices. The situation has been difficult for the research team to accept, but we have had to acknowledge our own limited capacities as well.

5. Summary and Conclusion

Despite all the operational challenges that we have faced, we still believe that community networks will play an important role in providing rural communications access, especially when market forces fail to deliver service in last-mile areas. However, a systematic review of community network strategy is required by policy makers and relevant stakeholders. CCNs will continue to face challenges without supportive and enabling environments,

which require coordination and commitment from the various stakeholders (government, academia, industry, and community). Finally, meaningful and sustainable impact requires more than a 2-year pilot project. To achieve impact in rural areas on a larger scale and in a more holistic way, a long-term roadmap for rural development, both in physical infrastructure and human resources, will be required.

Tables

Table 1: 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 (WiFI)
3	Dibut	San Luis	1032	Feb 1, 2018	Active (WiFi)
4	Diotorin	San Luis	578	May 30, 2018	Active (WiFi)
5	Market-Bacong-Ferry	Dingalan	500	Aug 29, 2018	Inactive
6	Dianao	Dilasag	300	Oct 17, 2018	Inactive
7	Dipasaleng	Dilasag	500	Jan 25, 2019	Inactive

Table 2. Table of 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/VBTSt barangay number	5.50	Per min
Calls from a VBTS barangay number to a n 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	0.50	Per SMS
Text/SMS from a VBTS barangay number to to a non-Globe/VBTS barangay number	1.00	Per SMS

Table 3. Technical and Commercial Operational Structure

Tier Level	Technical		Commercial	
	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 defined subscribers - Receive subscribers' concerns
L2	AnonymousSUC, 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

Table 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 minutes away. DMECC has members residing in Sites 6 and 7.

Figures

Figure 1. VBTS typical installation

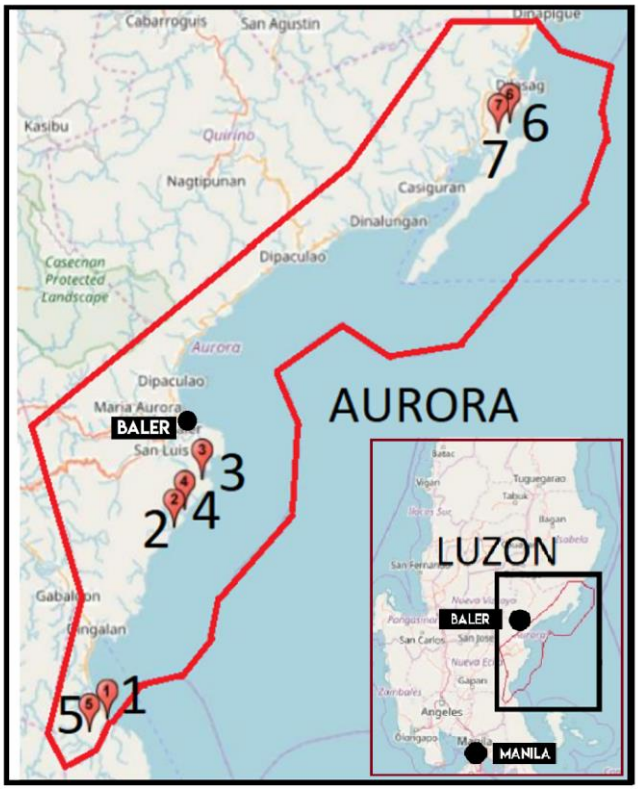

Figure 2. Map of deployment sites

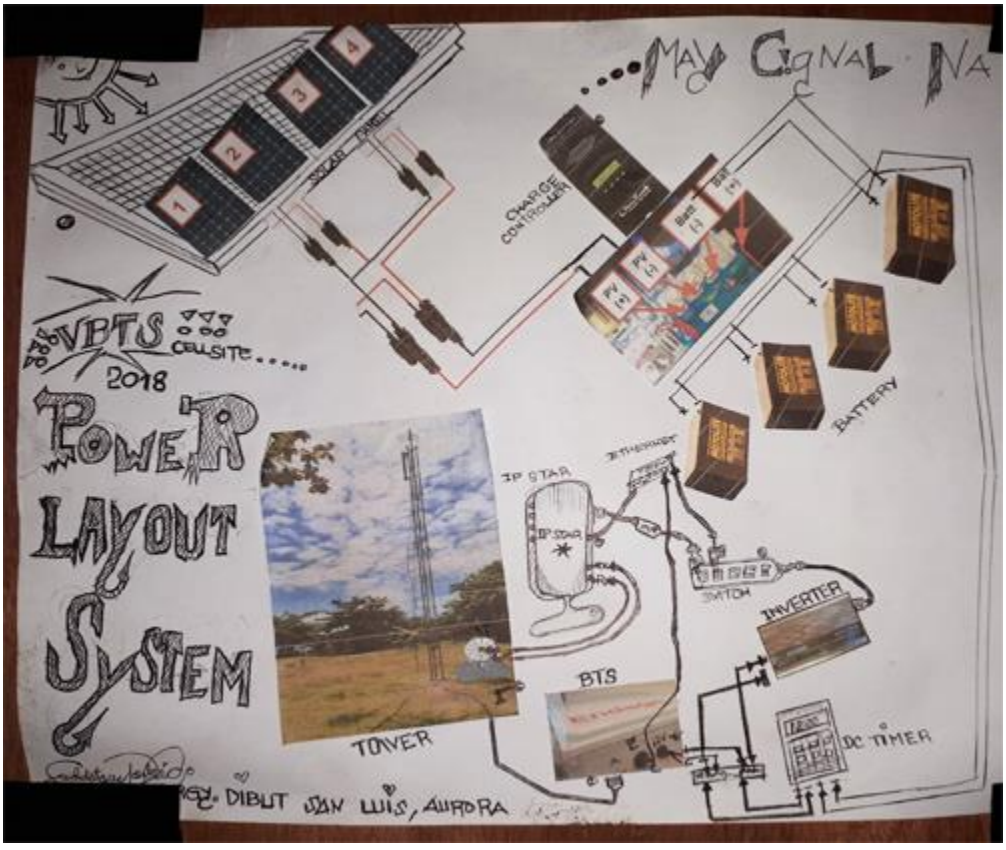

Figure 3. System diagram created by an L1 personnel.