LokaLTE: 600 MHz Community LTE Networks for Rural Areas in the Philippines

Calvin Artemies G. Hilario¹,², Mary Claire Barela¹, Mar Francis D. De Guzman¹,², Rizza T. Loquias¹, Ramon Vann Cleff B. Raro², Jean Jay J.Quitayan², and Joel Joseph S. Marciano, Jr.¹,²

¹Electrical and Electronics Engineering Institute, University of the Philippines - Diliman
²Advanced Science and Technology Institute, Department of Science and Technology
Quezon City, Philippines
{calvin, marfrancis}@astidost.gov.ph, j.marcianno@ieee.org

Abstract—In this paper, we present the case for opening up the 600 MHz spectrum for use by community-based cellular networks (CCN) offering LTE service to unserved and underserved populations in the Philippines. To this end, spectrum measurements were conducted at different locations in the country to establish a measure of utilization or occupancy of the UHF TV spectrum, specifically in the 600 MHz band. Our results show significant white space in the UHF TV band in rural areas, which opens the possibility for the reallocation or re-purposing of this spectrum for mobile networks to provide Internet connectivity in said regions. The 3rd Generation Partnership Project (3GPP), in particular, supports operation of the 4G wireless communications standard, Long Term Evolution or LTE, in the 600 MHz band through Band 71 (617-698 MHz), which is currently not adopted in the Philippines. With policy reform in mind, we have developed an LTE base station prototype, LokaLTE, that supports the case for opening Band 71 specifically for use by CCNs to offer connectivity in rural areas. To our knowledge, LokaLTE is the first LTE base station implementation using OpenCellular and srsLTE operating at Band 71. The low utilization of the 600 MHz band in rural areas and the accessibility of cost-effective infrastructure through LokaLTE are therefore intended to provide the national regulatory and planning agencies in the Philippines with evidence that underpins a policy of regionally selective allocation of Band 71 for use by CCNs to offer LTE service in underserved and unserved regions, thus helping to bridge the long standing digital divide in the country.

Index Terms—Spectrum measurements; Community cellular networks; LTE band 71; LTE base transceiver station

I. INTRODUCTION

Access to the Internet provides a pathway to information, services and better socio-economic opportunities, and is thus increasingly seen as a crucial enabler for improving the quality of life of communities. A World Bank-commissioned study estimates that a 10% increase in broadband penetration drives GDP growth by 1.21% in developed economies, and 1.38% in developing countries [1]. The United Nations recognizes the role of the Internet in driving global growth, with inclusive access as a key component of the Sustainable Development Goals [2]. In recent years, advances in mobile cellular technology and the proliferation of low-cost smartphones have lowered the barriers to entry, with about 49% of the world’s population accessing the Internet through mobile networks [3]. Despite these advancements, a significant portion of the world has yet to experience the value of the Internet and benefit from the opportunities that it brings.

One reason for this is the lack of quality, reliable, sustainable and resilient ICT infrastructure that will bring affordable and equitable Internet access for all. This is a challenge faced by many developing nations, including the Philippines, where mobile broadband penetration remains low in rural areas (Fig.1). In 2017, Internet connectivity in the Philippines ranked 101 among 176 economies in terms of affordability of ICT services [4], and is also considered to be among the most expensive yet slowest in the South East Asian region [5].

To address the issues of speed and affordability of Internet access, the Philippine government has recently encouraged more competition in the telecommunication space by inviting new players to compete with incumbent mobile network operators (MNOs) [7]. The introduction of a new player is expected to break the existing duopoly and drive competition in providing faster, more affordable, and more widespread Internet services to the public [8]. It is quite unlikely that the addition of new commercial MNOs will solve the digital divide as this new stimulus is still market-driven. Regulatory policies and business decisions largely shape the "digital architectures", which include business models and pricing structures that influence access and usage of ICT for the population [9]. The pricing and business models that emerge and are applied to mainstream ICT services of commercial MNOs are typically set so as to recover large capital expenses within a limited period, factoring in depreciation and the pace of technology obsolescence. We foresee that new commercial players in the Philippines will continue the "business-as-usual" approach where new deployments will prioritize areas where both population density and income levels are high, and prices are set to recover infrastructure investment. As such, these commercial services will continue to be beyond the reach of Filipino communities in rural and underdeveloped areas, thus perpetuating the connectivity gap.

Serving the last mile continues to face many logistical challenges such as difficult terrain, lack of transport infrastructure
Fig. 1: This map represents the coverage of GSM, 3G, and LTE mobile network of the two dominant telecommunication providers (A and B) in the Philippines (2020) [6].

and unstable or unavailable grid power that further discourage commercial investments. Fostering truly "free" competition in telecommunications and Internet service calls for policies that level the field for all, including small network operators in the countryside [10]. Hence, a more holistic approach in effectively addressing the digital divide would require exploring and combining efficient spectrum management, technical innovations, and non-traditional operational models. With recent global movement in these three spaces, we believe there is an opportunity that can be harnessed to address last mile ICT service delivery for rural populations in the Philippines.

II. BRIDGING THE DIGITAL DIVIDE THROUGH LOKALTE

Efforts aimed at addressing the challenges in last mile ICT service delivery for rural communities benefit from opportunities offered by recent initiatives or developments in spectrum management, technical innovations, and non-traditional operational models, which are described here.

1) Re-purposing Spectrum from Analog-to-Digital TV Migration: The global shift to digital TV is expected to yield "digital dividends" by freeing up spectrum that can be used for ICT service delivery [11]. The USA is the first country to reallocate the 600 MHz band for commercial mobile service following a successful broadcast incentive auction in 2017. Licensees were provided several options to relinquish a station’s spectrum voluntarily. These options include trading a UHF channel for a VHF channel, sharing a TV channel with another station, and stop broadcasting. The broadcast stations who voluntarily relinquished their spectrum were provided with a portion of the proceeds from the forward auction. On the other hand, broadcast stations that were involuntarily moved to a different UHF channel were provided with reimbursements for all the expenses incurred in moving to a different channel. Canada conducted a similar broadcast incentive auction which concluded in 2019 and Mexico is also following suit in 2020. Moreover, the 3GPP has standardized the new E-UTRA operating band as LTE Band 71 to facilitate the 600 MHz ecosystem development [12].

2) Thriving Ecosystem of Low-cost Network Equipment: Advances in mobile communications standards, coupled with lowering cost of off-the-shelf radio hardware, open up opportunities to develop innovative connectivity solutions. LTE is a 4G mobile communications standard for high speed wireless broadband access [13] and supports operation in multiple bands including the 600 MHz band. The proliferation of small-scale hardware manufacturers contributed to reduction in the market price of commercial off-the-shelf LTE base stations [14]–[16]. In addition, the increasing availability of low-cost software defined radios (SDRs) and open-source software has spurred efforts in developing cost-effective platforms that can be utilized for last mile service delivery [17], [18].

3) Build-Your-Own Network Movement: Community cellular networks (CCNs) [18]–[22] are emerging as an alternative solution to address the digital divide. CCNs are small-scale network infrastructure that are locally built, operated, and maintained, thus serving the local communication needs. Central to the operation of CCNs is access to spectrum. In Mexico, the national regulator provided CCNs a concession to spectrum access under a "social purpose" category [23]. In the Philippines, the Village Base Station (VBTS) project [24] addressed this issue on spectrum access by establishing a partnership with a commercial MNO in the Philippines that consented the use of their licensed 2G frequencies [22]. However, this agreement was time-bound, and forming such a partnership was a tedious and time-consuming process. In general, sustainability and proliferation of CCNs can be further supported by establishing institutional frameworks and policy reforms that would allow CCNs to use spectrum [10].

Given these developments, we present the case for opening up the 600 MHz spectrum, specifically Band 71, for use by CCNs to offer LTE service in rural communities in the Philippines. While it is not impossible for commercial MNOs to
access the newly freed 600 MHz spectrum, their market-driven approach suggests that network expansion in geographically isolated and disadvantaged areas will not be in their short-term roadmap. Until MNOs are ready to serve the last mile in these areas, we encourage the use of the 600 MHz spectrum for community cellular networks that can immediately address ICT needs in remote and rural areas. An intelligent spectrum management, that will allow non-interfering co-existence of both MNOs and CCNs, can also be exercised. We advance that such policy promulgation can be further strengthened by actual development and demonstration of 600 MHz LTE and by presenting a quantitative assessment of the availability of the 600 MHz band in rural areas. The spectrum measurements are presented in Section III while the development and testing of LokaLTE, an LTE base station operating at 600 MHz, are discussed in Section IV. In Section V, we describe possible policy directions that can be adopted based on the findings of this study. Finally, we conclude in Section VI.

III. QUANTITATIVE ASSESSMENT OF 600 MHZ SPECTRUM BAND AVAILABILITY IN THE PHILIPPINES

The National Telecommunications Commission (NTC) performs the mandate of managing spectrum allocation and use in the Philippines. According to the latest NTC database, a significant portion of the 600 MHz band is currently unassigned, notably in rural areas across the country. However, this database only provides a listing of licensed operators and does not reflect the actual state of spectrum utilization. To support the case for LTE at 600 MHz, quantitative evidence on actual spectrum usage needs to be gathered across the country through field measurements.

A previous spectrum survey in 2011 [25] measured utilization of the VHF (54-88 MHz; 174-216 MHz) and UHF TV bands (470-800 MHz) in Metro Manila, which showed 60% and 16% utilization of the VHF and the UHF TV bands, respectively. Another survey of the UHF band (410-960 MHz) was conducted in 2018 [26] where the spectrum measurements showed an increase in the UHF TV band utilization to 21.25%. These studies focused on fixed measurement points and in an urban setting. A recent spectrum survey conducted in 2019 [27] covered areas within the Western Philippine Nautical Highway and included both fixed and mobile measurements of the 470-698 MHz band.

We conducted a more extensive quantitative assessment and characterization of different urban, suburban, and rural environments at eight (8) different locations in the Philippines as shown in Fig. 2 and with spectrum measurements covering the UHF TV spectrum range from 470 MHz to 698 MHz. In this discussion, we focus on the portion of the 600 MHz band that corresponds to LTE Band 71 (617-698 MHz), which also coincides with fourteen UHF TV channels, i.e. channels 38-51. The spectrum measurements employed a multi-platform approach consisting of high-end measurement equipment such as the National Instruments PXIe software-defined radio, a mid-range implementation based on the USRP B200, and low-cost spectrum analyzers using the RF Explorer. Table I summarizes the technical specifications of the instruments used in spectrum measurements. In Table II, the measurement setup, consisting of an antenna, cables and a spectrum analyzer, for each location is specified. An example of an actual spectrum measurement setup is shown in Fig. 3.

Fig. 2: Spectrum measurement locations in the Philippines

Fig. 3: Spectrum monitoring setup deployed at DOST-ASTI.

The channel occupancy was estimated based on energy detection and a threshold value calculated using the Consecutive Mean Excision (CME) algorithm [28]. This methodology was adopted since it is better suited for occupancy measurements of multiple channels with equal bandwidths, such as in TV broadcasting [29]. The threshold was computed directly from the received signals and hence did not require unused channels or idle times to obtain the noise floor. Table II shows the mean
The findings of our spectrum survey confirm the low utilization of the portion of the 600 MHz UHF TV spectrum (Ch. 38-51) that spans Band 71. This is especially pronounced in rural areas. LokaLTE's front-end architecture is derived from Ettus Research due to its relatively lower cost and compact form factor. For LokaLTE, we selected the USRP B200mini SDR from Ettus Research due to its relatively lower cost and compact form factor. LokaLTE’s front-end architecture is derived from Ettus Research due to its relatively lower cost and compact form factor.

### TABLE I: Technical specifications of spectrum measurement systems

<table>
<thead>
<tr>
<th>ANTENNA</th>
<th>Gain (dBi)</th>
<th>Frequency Range (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-polarized</td>
<td>3</td>
<td>25-6000</td>
</tr>
<tr>
<td>Telescopic</td>
<td>2.1</td>
<td>20-1800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPECTRUM ANALYZER</th>
<th>Measurement frequency resolution (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI-PXI</td>
<td>0.001</td>
</tr>
<tr>
<td>USRP B200</td>
<td>0.1</td>
</tr>
<tr>
<td>RF Explorer (Handheld)</td>
<td>2</td>
</tr>
<tr>
<td>RF Explorer (IOT)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

estimated threshold values for each measurement. All locations used a threshold value acquired through this algorithm except for L3, where the threshold value was based on the equipment’s noise threshold (-100 dBm) [26]. The computed spectrum resource occupancy (SRO) and the total available channels in the 600 MHz band (Ch. 38-51) for each measurement location are also summarized in Table II.

The spectrum measurement results reveal the low utilization of the portion of the 600 MHz UHF TV spectrum (Ch. 38-51) that spans Band 71. This is especially pronounced in rural areas. In the semi-urban areas of Pangasinan and Oriental Mindoro, only about a quarter of the 14 channels are used on the average. In the urbanized area of Quezon City where presumably majority of the radio transmitters are located, 11 out of the 14 channels in the 600 MHz band were detected to be in use. Furthermore, more than half of the 600 MHz band is available in all measurement locations except in Metro Manila.

The findings of our spectrum survey confirm the low utilization of the portion of the 600 MHz UHF TV band, which motivates a review and possible reallocation of this radio spectrum to address pressing needs such as Internet connectivity. The relevant portion spanning Band 71 is specifically a logical candidate for reallocation, especially in rural areas for use by CCNs. To push this recommendation, we have built an LTE base station prototype that operates in Band 71, i.e. LokaLTE, in order to demonstrate the feasibility and availability of underlying technology that can be employed by CCNs. The details of LokaLTE are discussed in the next section.

### IV. DEVELOPMENT OF LTE SOLUTION FOR COMMUNITY CELLULAR NETWORKS

A locally-designed LTE Base Transceiver Station operating at Band 71, called LokaLTE, was developed to support the use of the underutilized 600 MHz spectrum in rural areas, and to demonstrate the feasibility of utilizing the technology for CCNs in the Philippines. LokaLTE leverages open-source software and low-cost commercial off-the-shelf hardware in its implementation.

### A. Architecture

Fig. 5 compares a traditional MNO vs CCN-based LTE network deployment. In a traditional LTE architecture, the Radio Access Network (RAN) is composed of a large number of stand-alone base stations called E-UTRAN Node B (eNodeB) [13]. The eNodeBs are located at the network edge to provide localized cellular coverage. RANs are connected to and controlled by the centralized core network or Enhanced Packet Core (EPC), located in one or more data centers of commercial MNO. This architecture requires high-capacity infrastructure in connecting the RAN and core network, and transporting high-volume of aggregated user data. Due to lack of available high-speed backhaul infrastructure in rural and remote areas, CCNs typically rely on bandwidth-constrained satellite and point-to-point wireless links such as microwave, WiFi, or TV whitespace (TVWS). Given the bottleneck, a CCN-based LTE network architecture moves all LTE components including the core network to the edge. This decentralized architecture resulted in measured backhaul reductions as compared to the traditional model [18]. Localized content caching can be also implemented at the edge of the network, which reduces latency.

The architecture of LokaLTE is shown in Fig. 4. The hardware components of the eNodeB include software-defined radio (SDR), auxiliary RF front-end, and antenna. Also, both the eNodeB and EPC cellular stack are running on a single computing device in our implementation.

### B. Hardware

In general, a Software Defined Radio (SDR) consists of a built-in reconfigurable radio frequency (RF) front-end, analog-to-digital converters (ADC), digital-to-analog converters (DAC), and a Field Programmable Gate Array (FPGA) for digital signal processing operations. This reconfigurability of the SDR means that it can be programmed to change its mode of operation from one wireless communications protocol to another, e.g. either as an LTE or Wi-Fi radio, by merely changing the software. Predominantly a platform for development or experimentation, the flexibility offered by SDRs is enabling more mainstream use especially with relatively rapid changes in technology. Most SDRs available in the market have a limited transmit power of approximately 10dBm (10mW), however. This RF output level is insufficient even for a picocell-sized base station and it is common to add an auxiliary front-end for amplification.

For LokaLTE, we selected the USRP B200mini SDR from Ettus Research due to its relatively lower cost and compact form factor.
## Table II: Summary of Results of the Spectrum Measurements in Various Locations in the Philippines

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Setup for spectrum sensing</th>
<th>Threshold (dBm)</th>
<th>Available 600 MHz channels (Ch.38-51)</th>
<th>Spectrum resource occupancy(%) (600 MHz band, Ch.38-51)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Dilasag, Aurora</td>
<td>Multi-polarized + RF Explorer (IOT)</td>
<td>-88.96</td>
<td>13</td>
<td>7.14</td>
</tr>
<tr>
<td>L2</td>
<td>Dagupan City, Pangasinan</td>
<td>Telescopic + RF Explorer (handheld)</td>
<td>-88.52</td>
<td>11</td>
<td>21.4</td>
</tr>
<tr>
<td>L3</td>
<td>Quezon City, Metro Manila</td>
<td>Multi-polarized + NI-PXI</td>
<td>-100.00</td>
<td>3</td>
<td>78.6</td>
</tr>
<tr>
<td>L4</td>
<td>Calapan City, Oriental Mindoro</td>
<td>Telescopic + RF Explorer (IOT)</td>
<td>-88.60</td>
<td>11</td>
<td>21.4</td>
</tr>
<tr>
<td>L5</td>
<td>Roxas, Oriental Mindoro</td>
<td>Multi-polarized + USRP B200</td>
<td>-90.94</td>
<td>8</td>
<td>42.9</td>
</tr>
<tr>
<td>L6</td>
<td>Malay, Aklan</td>
<td>Telescopic + RF Explorer (IOT)</td>
<td>-89.63</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>L7</td>
<td>Lapu-lapu City, Cebu</td>
<td>Multi-polarized + USRP B200</td>
<td>-90.46</td>
<td>9</td>
<td>35.7</td>
</tr>
<tr>
<td>L8</td>
<td>Koronadal City, South Cotabato</td>
<td>Multi-polarized + USRP B200</td>
<td>-87.28</td>
<td>12</td>
<td>14.3</td>
</tr>
</tbody>
</table>

*Spectrum resource occupancy refers to the ratio of number of channels in use to the total number of channels in the whole frequency band of interest [29]"

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**Fig. 5:** (A) Traditional LTE (B) CCN LTE

OpenCellular, an open source platform for enabling rural connectivity [17]. Since the OpenCellular front-end design originally operates at LTE Band 3 (1800 MHz), modifications on the design were applied to build a front-end that can operate at LTE Band 71. The LokaLTE front-end was further enhanced by adding filters, digital attenuators, a low-noise amplifier, a VSWR monitor, and a duplexer for Band 71 to allow the transmitter and receiver chains of the SDR share a single antenna. The output power achieved after the integration of the new auxiliary front-end is 38.5dBm or 7W.

**C. Software**

Since LokaLTE is targeted for small-scale community cellular networks, the use of a free and open-source solution is of primary consideration. There are now numerous open-source cellular stacks available that can run on a standard PC or even on a single-board computer. Some examples of open-source LTE cellular stacks are OpenLTE [30], srsLTE [31], and OpenAirInterface (OAI) [32]. We chose srsLTE for our LokaLTE implementation since its codebase is modular and easier to customize compared to the rest.

259
By default, these open-source software do not allow operation in Band 71. In previous LTE releases (LTE release 12 and below), only 4 bits (1-64) and 16 bits (0-66535) are allocated for the band indicator and the E-UTRA Absolute Radio Frequency Channel Number (EARFCN), respectively. In the case of LTE Band 71, the band indicator and EARFCN numbers are beyond the aforementioned allowable values. Thus, the corresponding system information block (SIB) messages that contain the band indicator and EARFCN information were modified to accommodate the required values for LTE Band 71.

D. Test Setup and Results

Functionality and throughput tests were conducted to verify LokaLTE’s performance. To avoid interference to and from other devices, LokaLTE was tested in a full-anechoic chamber (FAC). Fig. 6 shows the Linux-based host computer running srsLTE and connected to the USRP B200mini SDR through a USB3.0 interface. The SDR’s transmitter (Tx) and receiver (Rx) ports were connected to the auxiliary front-end and then to a coaxial cable that leads to a 5 dBi Log-Periodic PCB Antenna located inside the FAC, as shown in Fig. 7. Inside the same chamber is a commercial-off-the-shelf mobile phone, LG K30, with a programmable sim card that served as User Equipment (UE). The phone was set to engineering mode to enable advanced features such as "4G/LTE only mode" and the selection of a specific operating LTE band.

A screen showing the device under test (Fig. 6) confirms that the UE can connect to and continuously stream video through the developed LTE base station. Furthermore, the LTE air interface throughput and application-level throughput were evaluated. The former was measured using a network utility tool called iperf3 [33], with results shown in Fig. 8. The solid lines are the theoretical maximum downlink throughput while the dashed lines are the theoretical maximum uplink throughput. Uplink and downlink data rates were measured for each bandwidth setting.

In measuring application-level throughput, a custom Android-based application called the NetMesh Application [34] was installed in the UE. The NetMesh app generates and receives traffic to and from a test server located in the

![Fig. 6: LTE Band 71 base transceiver station inside a full-anechoic chamber facility](image)

![Fig. 7: Log-Periodic PCB antenna inside the full-anechoic chamber](image)

![Fig. 8: LTE air interface throughput performance obtained for UL/DL directions and 5/10 MHz bandwidths](image)

![Fig. 9: Application level throughput measured for UL/DL and 5/10 MHz bandwidth configurations](image)
V. Discussion

From Section III, the results of the measurement campaign in eight various locations in the country revealed low utilization of a large portion of the UHF TV band. The ongoing TV broadcast migration presents a timely opportunity to push for the freeing up of some parts of the 600 MHz band. According to the Philippines’ National Broadband Plan [35], frequencies that are freed up due to digital migration shall be reserved in favor of the public interest, which can certainly be argued in the case of rural connectivity and closing the digital divide. Specifically, CCNs can be enabled to offer rural Internet service through technologies such as 4G and LTE if granted access to the re-purposed 600 MHz spectrum.

In rural areas where the 600 MHz band is only partially clear, national regulators can devise incentives for current occupants to move to another frequency, such as the lower UHF TV bands, as part of on-going digital TV migration efforts. Furthermore, additional spectrum may also be freed up with the implementation of single frequency network (SFN) and channel sharing schemes that are possible in ISDB-T [36]. Meanwhile, in Metro Manila and other urban areas where TV broadcasting is more prevalent and the 600 MHz band therefore more heavily utilized, the status quo in the 600 MHz band may be preserved. In these areas, the presence of competition between multiple service providers help ensure better Internet accessibility, affordability and quality for the population. A “selective”, i.e. regional, re-purposing scheme for the 600 MHz spectrum for mobile broadband use, i.e. LTE Band 71, for use by CCNs in rural areas is thereby proposed. We add that the re-purposing of the 600MHz band may not help in bridging the digital divide if the spectrum will end up with commercial MNOs with no immediate plans of servicing the last mile in less profitable areas.

In Section IV, we presented the LokaLTE, a functional LTE base transceiver station prototype operating in the 600 MHz band. To the best of our knowledge, LokaLTE is the first implementation of OpenCellular and srsLTE at LTE Band 71. The demonstration of the LTE Band 71 prototype is intended to motivate relevant spectrum policy reform aimed at empowering community networks. In other words, the development of LokaLTE aims to provide a technology basis that supports the argument of re-purposing 600 MHz spectrum for LTE Band 71 for use by CCNs. While the current LokaLTE implementation features basic functionality that is adequate for demonstration purposes, there are ongoing hardware and software optimizations being carried out to bring the system closer to field deployment.

The development of LokaLTE is in line with promoting the growth and proliferation of CCNs in the Philippines, especially for serving rural areas. As small operators in geographically isolated or remote areas tend to have limited capital and resources for investment, affordability and accessibility of the technology is important. The use of commercial-off-the-shelf (COTS) hardware and open-source software hold promise for reducing capital and operating costs. Opportunities for local manufacturing of the LokaLTE system can help further lower the entry barriers for operators by making core equipment domestically available. Consistent with recommendations from International Telecommunications Union (ITU) [37] and the Internet Society [23] on regulatory flexibility and non-traditional spectrum management in support of rural coverage, the re-purposing the 600 MHz band for use by CCNs shall be pushed through dialogue with the Department of Information and Communication Technology (DICT), the NTC, TV broadcast stations and concerned civic organizations. Moreover, the planned establishment of the universal service access fund (USAF) can be implemented alongside the new policies, as the USAF can be tapped to provide incentives for developing community networks in the countryside [35].

VI. Conclusion

Closing the digital divide plays a vital role in the socio-economic advancement of a nation. The current top-down commercial approach in providing telecommunications service have so far been ineffective in bridging the connectivity gap that still exists across many parts of the world. Policy changes are necessary to embrace alternative and complementary ways to enable equitable Internet access. The establishment of CCNs embody a bottom-up approach that offers an increasingly viable option for filling the gaps in unserved and underserved areas. To be successful and sustainable, CCNs require access to dedicated spectrum. The initiative to re-purpose the 600 MHz for mobile broadband use in the Philippines, specifically to enable LTE Band 71, presents a potential solution to address the lack of dedicated spectrum for CCNs. The low utilization of the 600 MHz, as yielded by our measurements, and the demonstration of the LokaLTE functionality provide evidence that can be used by national regulatory and planning agencies in the Philippines to allow LTE Band 71 operation for rural CCNs. The access to dedicated spectrum and cost-effective LTE technology, coupled with the right policy framework, provide communities with the wherewithal to put up and sustain their own networks that bridge the digital divide and decisively propel the Philippines towards digital inclusion.

VII. Future Work

Future work on LokaLTE is focused on hardware and software improvements. In particular, the RF front end can be replaced with a single board implementation that enhances efficiency by reducing signal losses. The more compact implementation can also help bring down cost. The bandwidth between the host PC and USRP B200mini SDR is limited by the speed of USB interface, which can be replaced by a higher speed Ethernet interface. On the software side, the eNodeB and EPC software requires more robust testing prior to deployment. The development of a network administration system that can be used by national regulatory and planning agencies in the Philippines to allow LTE Band 71 operation for rural CCNs. The access to dedicated spectrum and cost-effective LTE technology, coupled with the right policy framework, provide communities with the wherewithal to put up and sustain their own networks that bridge the digital divide and decisively propel the Philippines towards digital inclusion.
system in a real-world environment and is poised to become the first community LTE network in the Philippines. The pilot demonstration will generate more empirical data and evidence that is expected to support the push for crafting responsive regulatory policies and additional spectrum reform that help bridge the digital divide in the country.

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REFERENCES

[12] “5gpp tr 36.755 v1.0.0 (2017-09), technical specification group ran for 600 mhz band for lte; (release 15), chap. 5.1.”