Cable Operators Neutral Network Exchange for Community Transformation (CONNECT)

1. General Information

- **Title of proposal:**
  Cable Operators Neutral Network Exchange for Community Transformation (CONNECT)
- **Relevance of Work Package (WP):**
  WP6: Helping to Bridge the Digital Divide in Developing Countries
- **Duration:** 24 months
- **Regional diversity**: Philippines
- **Keywords:**
  Internet Exchange Points, Software-defined Networking (SDN), Internet Measurement, Internet Data Analysis, Wireless Mesh Networks, Internet Tomography

2. Information on the participants

2.1. Principal Investigator (PI) / Leader

Roel M. Ocampo, PhD
Associate Professor, Electrical and Electronics Engineering Institute
University of the Philippines Diliman
Velasquez Street, Diliman, Quezon City, Philippines 1101
roel.ocampo@eee.upd.edu.ph
Tel: +63-2-981-8733 / Fax +63-2-925-2957

The Principal Investigator has been involved in network infrastructure projects for the past 20 years, including supervision and oversight of the design of computer networks in multiple locations nationwide. He is currently the Program Leader of the *PCARI Research and Instructional Infrastructure for Mentoring and Collaboration*, a project funded by the Philippines' Commission on Higher Education with a budget approximately worth EUR 4.8M, designed to provide connectivity and collaboration infrastructure and facilities to selected state universities and colleges nationwide. He was very recently the Program Leader of the *Bayanihanets: Building Robust and Sustainable Cooperative Community Networks*, a research effort on the development of community wireless mesh networks, funded by the Philippines' Department of Science and Technology (total program-wide funding approximately EUR 405K)

2.2. List of Collaborating Participants

No.	Name	Organization	Country	Email
1	Roel Ocampo	University of the Philippines Diliman	PH	roel.ocampo@eee.upd.edu.ph
2	John Robert Mendoza	University of the Philippines Diliman	PH	
3	Tyrone Paynor	Telmarc Cable	PH	
4	Bayani Benjamin Lara	Advanced Science and Technology Institute	PH	
5	Nemesio Macabale Jr	Central Luzon State University	PH	

3. Proposed Activities/Programs

Cable operator networks are a potentially powerful force that may be harnessed to provide high-speed yet affordable Internet connectivity in underserved areas, due to widespread service coverage and existing installed infrastructure. However, with many cable operators being relatively late entrants in the Internet service business, there is a need for the industry to quickly leapfrog and transform in order to provide competitive services that are affordable to users, profitable for providers, and able to offer new and socially-relevant services beneficial to individuals, their families, and the larger communities to which they belong.

CONNECT (Cable Operators Neutral Network Exchange for Community Transformation) aims to achieve these goals by fostering cooperation and interconnectivity among cable TV operators and providing technologies that would enable the delivery of competitive and new services. This will be done by establishing an industry-initiated open and neutral Internet exchange point, conducting intensive training, advocating the use of best practices and standards such as IPv6, and harnessing new technologies such as software defined networking within the network and at the exchange. Although these will be done within the broad context of providing Internet service, there will also be a parallel effort to transform and evolve the cable industry's core business -- video content delivery -- to this new service model, and harness this core expertise for new, community-focused services such as remote healthcare and educational content.

In line with the mission of driving competition, create new technologies, and to expand reach, community-centric endeavours will be employed to promote penetration in remote areas where it is infeasible for telecommunication companies to deploy infrastructure for Internet services. This opens up possibilities to provide basic yet sustainable network services in areas where logistical assumptions and economical gain are less than ideal. These goals are to be accomplished largely in part by cross-multiplying the soon-to-be-unleashed potential of cable TV operators with wide-scale implementation of community wireless mesh networks within rural areas, to rapidly expand Internet access to previously unserved areas.

3.1. Overview/Background

Cable television (CATV) operators currently enjoy a marginal share of the fixed broadband Internet market in the country. Nevertheless, cable network operators hold extensive fixed-line coverage even in distant and suburban areas where telecommunication companies only have wireless infrastructures in place. Leveraging on this unique resource, cable networks can be a powerful force that can be harnessed to provide affordable and high-speed Internet connectivity in underserved areas which could strengthen their competitive position in the local Internet market.

Cable network operators have to face and overcome several challenges in order to significantly gain a bigger share of the local Internet market. Among these are:

1. There is a need to transform the existing infrastructure from one that supports the delivery of (almost exclusively) video content, to one that is able to deliver triple-play services *and* additional new services that will provide a competitive edge. Before any such transformation in infrastructure and services may be made, there should be requisite capability-building in terms of technology know-how to reengineer and operate these flexible and forward-looking infrastructures
2. The cable industry needs to band together organizationally and physically interconnect in order to achieve better purchasing leverage, economies of scale, and attain a critical mass that puts it in a better position to compete with traditional large telecommunications operators. From a technical perspective, interconnectivity and domestic peering between local cable operators will ensure better domestic network performance, more profitable use of expensive transit links, access and lower pricing for higher-capacity international transit, and attractiveness for content providers to colocate local content caches.
3. Even with the already-extensive legacy cable TV infrastructure, there are still geographically large areas that remain digitally underserved. Covering these areas would require large capital investments that would be difficult to recover due to poor profitability. Despite the possibility of serving new areas by unlocking the latent potential of cable TV providers, new access infrastructure approaches and business models will have to be developed and applied in order to expand service coverage far beyond the current geographic reach of legacy infrastructures.

Towards this end, we propose a multi-stakeholder, multi-pronged strategy that may be described by the following: engagement, enhancement, exchange, enablement, and empowerment. Each element of the strategy and the corresponding project objectives are discussed in the next section.

3.2. Strategies and Objectives

Our proposed approach consists of the following elements:

Strategy 1: Engagement. We believe that challenging problems like these require novel multi-stakeholder approaches in order to find creative solutions. Towards this end, the following parties will be engaged and work side by side in this proposed project:

- *The cable industry*. As the main beneficiary of the technology intervention and capability-building effort, the cable industry has to be directly involved in steering and implementing this project. The principal industry representative here will be Telmarc Cable, a key industry player that services areas outside Metro Manila and which has alliances and partnerships with other cable operators. The fact that it services suburban and rural areas puts Telmarc in a unique position of familiarity with the problems and issues providing access in challenging areas, and also ensures that the project will test and deploy solutions where they are most needed.

- *Local R&D agencies and NREN operators*. PREGINET, the local NREN, is operated by the Advanced Science and Technology Institute, which will be another partner in this project. PREGINET is not only a network but also a rich resource for expertise and advanced networking technologies and services. The project will therefore offer unique opportunities for technology transfer and transformation. Furthermore, physical interconnection between the cable TV operators and PREGINET are likely to uncover opportunities for mutual infrastructure growth, and enable resource sharing and access such as to content delivery caches and similar resources. Furthermore, the long working relationship between PREGINET and initiatives such as TEIN will ensure that the overall project objectives and outcomes are aligned and transparently shared with it and similar entities.

- *Academe.* Both the University of the Philippines Diliman and the Central Luzon State University will provide academic and research expertise, leveraging R&D expertise in areas such as software-defined networking and community wireless mesh networks. These universities have actually had recent research projects involving pilot deployments of community mesh networks, and this experience could be leveraged and scaled for a proposed wider deployment. Furthermore, active research interest and activities in software-defined networking may also be brought to the table in order to explore the provisioning of flexible and future-proof infrastructures for cable TV providers.

- *Communities and local government units*. Even if we are able to unlock and harness the potential of cable TV networks to provide new digital services to previously unserved areas, as business entities, they will need to overcome the difficult challenge of providing access infrastructure in less-than-profitable areas. Here we intend to explore a

novel way of solving the problem: engage the actual target market itself so that it becomes empowered to be part of the solution rather than the problem. Jointly with communities and their respective local government units, we will pilot-deploy sustainable community-driven and community-operated mesh networks to extend access far beyond the reach of cable TV operator infrastructures. Building on the experience and successes of similar efforts such as *guifi.net* in Spain and the smaller local pilot *Bayanihanets*, we propose a novel hybrid approach where community-based and community-driven bottom-up mesh networks are collaboratively built in partnership with commercial providers, NRENs, and the academe.

Strategy 2: Enhancement. We propose to embark on large-scale capability building between and among project participants, and when feasible, the wider public. The bulk of the capability-building activities such as training will naturally be cable TV providers. However, given that we intend to explore a novel strategy of engaging and empowering communities to help build their own access networks, we will also program training and capability-building activities targeted towards developing community-based operators and technical contacts. Finally, in order to absorb and transfer the latest technologies and best practices, exposure and involvement in multilateral organizations such as the IETF, and APNIC, events such as APRICOT and other conferences, and linkages with other entities such as NSRC will be programmed.

Strategy 3: Exchange. A key technical component of this proposal will be the formation of an Internet exchange point targeted to, but not exclusively for, cable TV operators. This will ensure good network performance particularly in the exchange of domestic traffic, and hopefully promote the development and distribution of local content. An IXP will also make it economically feasible and attractive for foreign content providers to host local caches, and for large providers to offer high-capacity transit links. We intend to interconnect the proposed IXP to PHOpenIX, the local carrier-neutral IXP, in order to further exchange traffic with other domestic ISPs and to gain access to CDN caches hosted in the latter exchange. The IXP-to-IXP interconnection effort will be facilitated through the involvement of the Advanced Science and Technology Institute and PREGINET. To ensure sustainability and ownership by the target stakeholders, the IXP will be physically hosted and operated by a consortium of cable operators. To allow for continuous technological growth, the set up will be mirrored in the partner academic institutions for experimental and R&D purposes.

Towards this end we plan to:

- Increase the amount of network traffic exchanged across the PhOpenIX switching fabric.
- Improve the reliability, speed and quality of access of cable operator networks to domestic Internet content.
- Improve the reliability, speed and quality of access of cable operator networks to popular Internet services e.g. video streaming and search engines.
- Reduce transit data volume of cable operator networks.
- Increase peering activity among domestic autonomous systems.

Finally it should be noted that since CONNECT will be interconnected with PHOpenIX, and by implication will be directly exchanging traffic with partners of PREGINET, the local NREN, this offers a very unique opportunity of linking up users and subscribers from previously-underserved areas (which will be serviced by cable TV companies and community-driven access mesh networks) directly with the other end of the spectrum represented by NREN users: institutions of higher learning, R&D institutions, and government agencies. This represents the bridging of a previously very wide gap between digital haves and have-nots, and as such, may offer very unique and new developmental opportunities for the future.

Strategy 4: Enablement. To ensure a flexible and future-proof infrastructure for cable TV operators, we intend to employ software-defined networking (SDN) technology both in the proposed cable operator IXP, and will promote the use of the same throughout partner cable TV network infrastructures. The vision is for the technology to enable the flexible and rapid development and deployment of the next generation of services beyond 'plain' Internet access. On the IXP end, we hypothesize that SDN will enable us to push the development of a new class of Internet exchanges that support rich information and services for peering participants, making it attractive and practical for new members to join. On the provider edge, SDN may enable not only Internet access, a transform on how the cable industry will deliver in the future what it has singularly done before: video content. Future modes of video delivery and content may include community-relevant yet QoS-sensitive services such as interactive educational content, rural healthcare, managed IoT security, community CCTV, hazard warning and sensor data, and others.

Specifically we plan to:

- Enhance visibility on the state of domestic Internet routing.
- Enhance visibility on the amount of traffic exchanged over the IXP switching fabric.
- Reduce IXP network and service outages.
- Strengthen IXP network security.

Strategy 5: Empowerment. The challenge of providing access infrastructure in geographic areas considered to be commercially non-profitable is difficult to solve using traditional methods and metrics of provider-driven investment. An area considered to be unprofitable by an incumbent telecommunications provider is likely to also be unprofitable even from the point of view of a cable TV provider, even though the latter might have some advantage in terms of existing infrastructure, service presence and relationship with the community. However, successful bottom-up community-driven infrastructure development as demonstrated by the 34,000-node *guifi.net* in Spain, and our local experiences with cooperative community resource sharing in the local *Bayanihanets* pilot deployment suggest that we can employ the same strategy of empowerment to communities in an effort to further develop access infrastructure. By employing this strategy -- directly engaging communities and working with their respective local government units -- we aim to create sustainable meshed access infrastructures in order to achieve coverage areas far beyond the existing legacy cable TV infrastructures.

In this component, we will organize and pilot-test *CO-OWNs: Community Operated Wireless*

Networks. We will install a fiber backbone from a Telmarc Cable node, stretching all the way to Barangay Calawis in Rizal Province, a digitally underserved area northeast of Manila. Along the fiber path, communities will be equipped and trained to maintain and operate their own mesh networks. We will also leverage the experience of some of the project partners with the *Village Base Station Project*, a collaborative research project on community-operated cellular services jointly done by the University of the Philippines and the University of California Berkeley. We will look at not only the challenge of technical sustainability but also examine the matter of financial sustainability as well.

Our targets include:

- Around 10 community-operated mesh access networks along the fiber path, with 10 mesh nodes on average per cluster.
- Trained 1-2 contacts per community cluster
- Sustainability model for community-operated access mesh network

3.3. Details of Activities/Programs

In order to efficiently implement our strategy and successfully achieve our objectives, numerous activities were identified to be carried out:

- Ensure constant **ENGAGEMENT**
    - Organize regular discussions participated by representatives from the academe, government, cable industry, and community so as to continuously carry out communications on key matters relating to the execution of the project.
    - Participate in events organized by the cable network industry, such as the Philippine Cable TV Association (PCTA) and Federation of International Cable TV and Telecommunications Association of the Philippines (FICTAP); the government, such as the Advanced Science Technology Institute; and local Internet community, such as Philippine Network Operators Group (PhNOG) and Internet Society (ISOC-PH), as resource speaker to promote the project activities and raise awareness for its expected benefits.

- Accelerate skills **ENHANCEMENT**
    - Organize local trainings on advanced BGP operations for cable operator network engineers to increase their understanding of inter-domain network protocols necessary for operating critical Internet infrastructures, as well as improve their technical capabilities in managing IP networks.
    - Organize local trainings on software-defined networking for cable operator networks to enhance their skills and upgrade their knowledge on recent developments in networking.
    - Organize local trainings on IXP operations and management for cable operator networks in order to build organic capability in administering network services operating in the IXP environment and guarantee its continuous operations.
    - Deploy an online repository for storing technical documentation and digital

resources relevant to the operations and implementation of CONNECT so that stakeholders can freely download the work materials and get informed about the technical architecture of the project
    - Deploy an web portal for disseminating information about the operational status of CONNECT services and for releasing significant updates and reports during the execution of the project so that the stakeholders and target audience can follow the meetings and get informed of the project outcomes.
    - Participate in international trainings and workshops such as Asia Pacific Regional Internet Conference on Operational Technologies (APRICOT) in order to build knowledge around new technologies and learn best practices in managing IP networks from seasoned engineers.
    - Participate in international academic conferences such as SIGCOMM in order to engage experts and prominent researchers in the computer communications and networking field to exchange ideas and solicit valuable feedback with the goal of improving the project implementation, and possibly, report the research findings generated from the project.

- Facilitate local Internet traffic **EXCHANGE**
    - Establish a switching fabric for facilitating multi-lateral connectivity between members of CONNECT. This environment will allow cable operator networks to configure BGP peering sessions between over the fabric.
    - Set up a virtual server compute platform to enable rapid provisioning of computer and storage resources for deploying network applications and creating services.
    - Deploy a software-based route server designed to facilitate the exchange of routing information between autonomous systems.
    - Provision a dedicated fiber optic link between CONNECT and Philippine Open Internet Exchange (PHOpenIX). This will open up opportunities for cable TV operators to exchange traffic with incumbent ISPs present in PhOpenIX and gain access to edge servers deployed by CDNs.
    - Develop a network monitoring and data analysis platform composed of software applications that collect streaming traffic traces from the switch, routing information from the route server, and active measurements from probing devices distributed across the Internet. All of these network data are processed with the goal of generating real-time traffic statistics and analyzing historical traffic trends and usage patterns for evaluating network performance.

- Driving innovation **ENABLEMENT**
    - Deploy an SDN controller designed to manage and control the forwarding functions of the switching fabric. This component will enable rapid development of applications and services that perform unique and novel network functions.
    - Develop an SDN-based application designed to suppress unwanted network traffic flowing from the IXP fabric. This may be traffic from anomalous sources or protocol behavior that affects the overall performance of the IXP environment. The application will be driven by actionable insights provided by the Internet

data analysis platform.

- Promote inclusiveness and community **EMPOWERMENT**
    - Provision a dedicated fiber optic line extending the cable operator network to the missionary barrio of Calawis, Antipolo City in the fringes of the Rizal province. This communication line serves as backhaul link of the wireless community networks that will be deployed along its path.
    - Deploy wireless access points in select households in several sites along the route of the fiber optic link. These devices are configured to establish a mesh wireless network that provide Internet access to the community in the area.
    - Organize trainings for technical contacts from the community on wireless mesh network operations so as to build the technical skill set required to maintain and operate the wireless community infrastructure.
    - Organize orientation activities with members of households in the community on the proper and efficient use of the wireless mesh network devices to ensure upkeep and maintain the quality of network service.
    - Identify key models on sustainability in the community-operated wireless networks context.

These activities were programmed to produce deliverables that will provide tangible outputs for assessing the project's development and completion. These deliverables are detailed in the next section.

3.4. Deliverables

In order to provide the stakeholders and the general public with accurate representation of the CONNECT's progress, we aim to produce the following deliverables within the the project duration:

Deliverable (number)	Deliverable name	*Type	**Delivery date (in months)
1	Memorandum of Understanding (MOU) between project partners	Report / Document	2
2	Transport circuit/dark fiber between PhOpenIX and CONNECT	Hardware	3
3	Software-defined network (SDN) switch equipment	Hardware	3
4	Virtual server platform	Software	1
5	BGP route server	Prototype	1
6	Network monitoring system	Prototype	1
7	Internet data analytics platform	Prototype	1
8	Wireless mesh nodes	Hardware	15
9	Project wiki portal	Website	1
10	Software-defined network training	Training	3

11	Border gateway protocol (BGP) and advanced routing training	Training	3
12	IXP network services knowledge transfer training	Training	3
13	Philippine Network Operators Group (PhNOG) meeting presentation	Report	1
14	Philippine Cable TV Association (PCTA) convention presentation	Report	1
15	Fiber optic line extending from Telmarc to Calawis, Antipolo	Hardware	6
16	Wireless mesh network nodes	Hardware	24
17	Community-operated wireless network operations training	Training	3

3.5. Milestones & Timeline

The CONNECT project is proposed to be successfully implemented in a 24-month period. The project lifetime is broken down into significant milestones indicating the completion of key activities, objectives, and target deliverables. Most of the activities can be performed in parallel thus multiple milestones can be achieved simultaneously.

Milestone No.	Milestone name	*Due date (in month)	**Means of verification
1	Project kickoff and MOU signing with project partners	**March 2018**	Memorandum signed off
2	Transport circuit/dark fiber procurement	**June 2018**	Delivery of the equipment completed
3	Compute, storage, and network equipment acquisition	**June 2018**	Delivery of the equipment completed
4	Wireless mesh nodes acquisition	**June 2018**	Delivery of the equipment completed
5	Installation, testing and commissioning of virtual server platform	**October 2018**	Successful virtual machine creation and deletion
6	Installation, testing and commissioning of BGP route server platform	**October 2018**	BGP application running and validated
7	BGP peering configuration	**October 2018**	Successful BGP

			peering with PhOpenIX route server
8	Network monitoring system deployment	**October 2018**	Application running and producing traffic statistics
9	Internet data analysis platform development	**October 2018**	Application running and generating historical statistics
10	Wireless mesh nodes deployment	**October 2018**	Internet access through the mesh network successful
11	Project portal / wiki development and deployment	**June 2018**	Website released and validated by users
12	SDN training	**March 2019**	Training completed
13	BGP and advanced routing training	**April 2019**	Training completed
14	IXP network services operation training	**May 2019**	Training completed
15	Presentation in PhNOG meeting	**June 2019**	Presentation completed
16	Presentation in PCTA / FICTAP convention	**April 2019**	Presentation completed
17	Community wireless mesh network operations training	**June 2019**	Training completed

A gantt chart illustrating the timeline for activities listed in this section is attached as a separate document. Please refer to APPENDIX C for details.

3.6. Risk Assessment

Several factors may affect the CONNECT project baseline and its ultimate objective of improving Internet connectivity in the country. We anticipate these risks and managed them accordingly through risk-mitigation measures and approaches that are practical and realistic.

Description of risk	Impact (L/M/H)	Likelihood (L/M/H)	Proposed risk-mitigation measures
Availability of dedicated transport circuits / dark fiber into the data center	H	M	Acquire leased lines from existing telcos servicing the area
Cost of fiber optic link between PhOpenIX and CONNECT	H	M	Acquire leased line from existing telcos servicing the area
Feasibility of fiber optic link between Telmarc Cable and Calawis,	H	L	Utilize wireless transmission backhaul link

Antipolo			
Local availability and cost of wireless mesh node devices	M	M	Online purchase
Availability of SDN switches in the local market	H	M	Online purchase
Availability of viable data center facility	H	L	Co-locate in a government data center
Regular maintenance of the server, storage, and network equipment	L	L	acquire extended maintenance agreement with vendor
Availability of stable power source in the community sites to energize the wireless access node devices	M	M	Acquire and distribute solar panels with batteries to the households

4. Resources to be committed/Budgets

- Please refer to the Appendix B for the 'Budget template' and its guidelines and fill in the template in detail as itemized. A break-down cost quotation for estimated budget will be in Euro (€).

5. Expected Impacts

5.1. Benefits to TEIN and its Community – Indicative Log-frame Matrix

The CONNECT project is a cooperative endeavor undertaken by the academe, government, and business sector to enhance the availability, reliability and affordability of Internet access in the Philippines. Concomitantly, the results are expected to gain a significant contribution to TEIN's objective of connecting the Asia's research and education communities by enhancing the technical capacity of engineers in the region and promoting the development of innovative Internet applications. Specific indicators are provided in order to assess the impact of the project to the greater TEIN community.

Indicators	Results/Benefits	Means of verification	Assumptions
Number of promotional conferences and workshops attended	Contribution and benefits of the project is disseminated to the public community	Certification from the event organizers	Presentation and topic is accepted in the conference program
Number of "train-the-trainers" with network engineering expertise	Standard training courses for network engineers implemented	Training module for advanced IP network routing and community-operated wireless network operations	Prospective trainers have participated in APRICOT

IXP link utilization data	Improved performance in accessing locally- sourced content	Aggregate traffic statistics	Participants implement BGP on their networks
Number of advanced products & services deployed	Reduce network outages and improve Internet access reliability	Monitoring events recorded	Wireless mesh nodes and virtual server platform are maintained online and operational
Number of people with access to the Internet nationally & remote areas in particular	Enhanced social and education services	Wireless mesh network aggregate traffic statistics	Households in the community maintain upkeep and ensure proper operation of wireless mesh node devices

6. Visibility/Dissemination plan

Our dissemination plan aims at increasing the impact and visibility of the CONNECT project regionally and at the national level. The project has the primary objective of developing an innovative avenue by improving long-term strategic collaboration between the academic and research institutions, the national and local government, and the business sector represented by the cable operators, while simultaneously enhancing the development of sustainable Internet access infrastructure advancements in rural communities. To wit, the dissemination plan targets to achieve the following goals:

- *Raising the awareness for the CONNECT project, its project activities and expected results*
  The awareness for the CONNECT project will be raised through two different approaches: enhancing digital readership and speaking engagements. Enhancing digital readership intends to connect and engage with stakeholders and the general public about the project activities through news published on the project's website and websites of each partnering institution. Speaking engagements in local conferences and meetings is excellent way for the project to generate publicity and positive exposure. This activity will be accomplished by regularly participating as resource speakers in the Philippine Network Operators Group (PhNOG) meetings and Internet Society (ISOC) sponsored events. In both of these approaches, we utilize the advantages of traditional and digital communication media (such as social networking platforms), and press releases for widening our reach and exercising transparency.

- *Motivating the cable operator industry as well as households in rural communities to participate and use the benefits of the Internet exchange facility and wireless mesh network established during the project duration*
  The engagement of the cable industry and the target rural communities is of primary importance for the success of the CONNECT project so one of the main tasks of this strategy will be to determine the leaders of the communities and representatives of the cable operator networks that will act as the initial point of reference for the dissemination strategy. It is therefore necessary that a list of the potential cable operator networks and rural communities be identified before the project kick-off meeting. A responsible person from each partnering institution will be appointed for contacting their respective communities or organization.

- *Dissemination through publication and communication of results*
  The partners are encouraged to present the project results and outcomes on national and international conferences and other relevant scientific and business events. Conferences such as those organized by SIGCOMM and APNIC serve as excellent venues for institution partners to exchange ideas with the wider international community and solicit feedback on the research and operational methods being executed in the project.

7. Sustainability of the Activity/Program

CONNECT is initially owned and operated by the cable network industry. The primary objective of CONNECT is to organize network entities which share the same peering objectives and inclination through the establishment of an Internet exchange point (IXP) that offers a flexible, dynamic and transparent environment for developing new and socially-relevant network services.

We envision CONNECT as the primary Internet Exchange Point (IXP) that interconnects network entities in other industries and ISPs operating in the southeast region of the country. In order to achieve this goal, CONNECT must be able to preserve the trust of its incumbent members and gain the confidence of the local Internet community by demonstrating the technical capability to manage and operate a robust and transparent Internet infrastructure. To support its operations, CONNECT members may adopt a non-profit charging model which allows the creation of a trust fund that will amortize the operating expenses for maintaining the transport circuits / dark fiber facility, data center co-location and maintenance of equipment. The trust fund can also be tapped to sponsor or subsidize attendance to local and international training workshops of technical staffs. Through this mechanism, incumbents are reassured that the facility will continue to operate reliably and scale adequately as membership grows.

For the community-operated access mesh networks, sustainability models will be considered by studying the *guifi.net* model, the *Bayanihanets* pilot resource-sharing network experience, and the *Village Base Station Project* results and findings.

APPENDIX A - Information on the participants A1.

CV's of PI and his/her publication list

Please refer to the attached document named "**APPENDIX A - Principal Investigator CV.pdf**".

A2. Publication lists of collaborating partners/participants

Peering, Internet traffic analysis and Internet tomography

J. R. Mendoza, R. Ocampo, I. Montes, and C. A. Festin. Efficient Feature Extraction for Internet Data Analysis using AS2Vec. (To appear) *32nd ACM SIGAPP Symposium On Applied Computing (SAC 2018)*, Pau, France, April 2018

J. R. Mendoza, J. Racca, I. Montes, R. Ocampo and C. A. Festin. Peering Into Peering: Building Better Tools for Better Peering Decisions. *2016 26th International Telecommunication Networks and Applications Conference (ITNAC)*, Dunedin, 2016, pp. 202-207. doi: 10.1109/ATNAC.2016.7878809

M. Cruz, R. Ocampo, I. Montes and R. Atienza. Fingerprinting BitTorrent Traffic in Encrypted Tunnels Using Recurrent Deep Learning. (To appear) *4th International Workshop on Information and Communication Security (WICS 2017)*, held in conjunction with CANDAR'17, Aomori, Japan, November 2017

Community mesh networks and applications

I. Montes, M. Cruz, A. Remillano II, M. Villanoy, L. Beltran II, R. Ocampo and C. Festin. Tangible Sharing, Invisible Mechanisms: The Design and Implementation of the BayanihaNets Access Sharing Network. *ACM SIGCOMM Global Access to the Internet for All (GAIA) Workshop*, August 2016, Florianópolis, Brazil.

J. V. Santos, D. V. Torres, M. K. Villanoy, C. A. Festin, J. N. Doctor and R. Ocampo. Rapid Mobile Development with ARC: Application Framework for Robust Communications for Disaster Risk Reduction and Management. *IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, New York, NY, 2016, pp. 1-6. doi: 10.1109/WiMOB.2016.7763186

I. Montes, J. Chua, J. M. Cruz, A. Remillano, J. D. Young, R. Ocampo, and C. Festin. Streaming 4K/UHD Video to the Rest of Us: Can Bandwidth Sharing Help? *IEEE 16th*

International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), June 2015, Boston, USA. http://dx.doi.org/10.1109/WoWMoM.2015.7158220

Wireless mesh networks and sensor networks

N. A. Macabale, Load Aware Routing in Wireless Mesh Networks: Which Is The Right Metric? (To appear) *IEEE 42nd International Conference on Local Computer Networks Workshops*. Singapore, October 2017

M. C. B. Gragasin, M. P. A. Talplacido, and N. A. Macabale. Throughput Evaluation of Raspberry Pi Devices on Multi-hop and Multi-flow Wireless Sensor Network Scenarios. *International Conference on Signals and Systems (ICSIGSYS)*, 2017, pp. 256–260.

I. Montes, R. Parmis, C. Festin and R. Ocampo. Multipath Bandwidth Scavenging in the Internet of Things. *EAI Endorsed Transactions on Cloud Systems Special Issue on IoT as a Service*, February 2015, 15(1), ISSN 2410-6895, http://dx.doi.org/10.4108/cs.1.1.e3. (Extended version of paper with the same title presented at the First International Summit, IoT360 2014, Rome, Italy, Oct 2014)

M. Cruz, I. Montes, A. Remillano, N.Tiglao, R. Ocampo, C. Festin, and N. Macabale. Extending Wireless Sensor Network Lifetimes Through Channel Load Aware (CLAW) Routing. *International Conference on Information Networking (ICOIN)*, 2017, (pp. 372–376). https://doi.org/10.1109/ICOIN.2017.7899461

N. Macabale, R. Ocampo and C. Festin. Channel Load Aware Routing in Wireless Mesh Networks. *16th International Conference on Advanced Communications Technology (ICACT2014)*, PyeongChang, Korea, Feb. 2014

APPENDIX B - Resources to be committed/Budget (separately distributed) B1.

Please refer to the attached document named **"APPENDIX B - Consolidated Budget of Action.pdf"**

APPENDIX C - Gantt Chart

Please refer to the attached document named **“APPENDIX C - CONNECT Gantt Chart of Activities.pdf”**.

APPENDIX D - CONNECT Network Architecture Diagrams

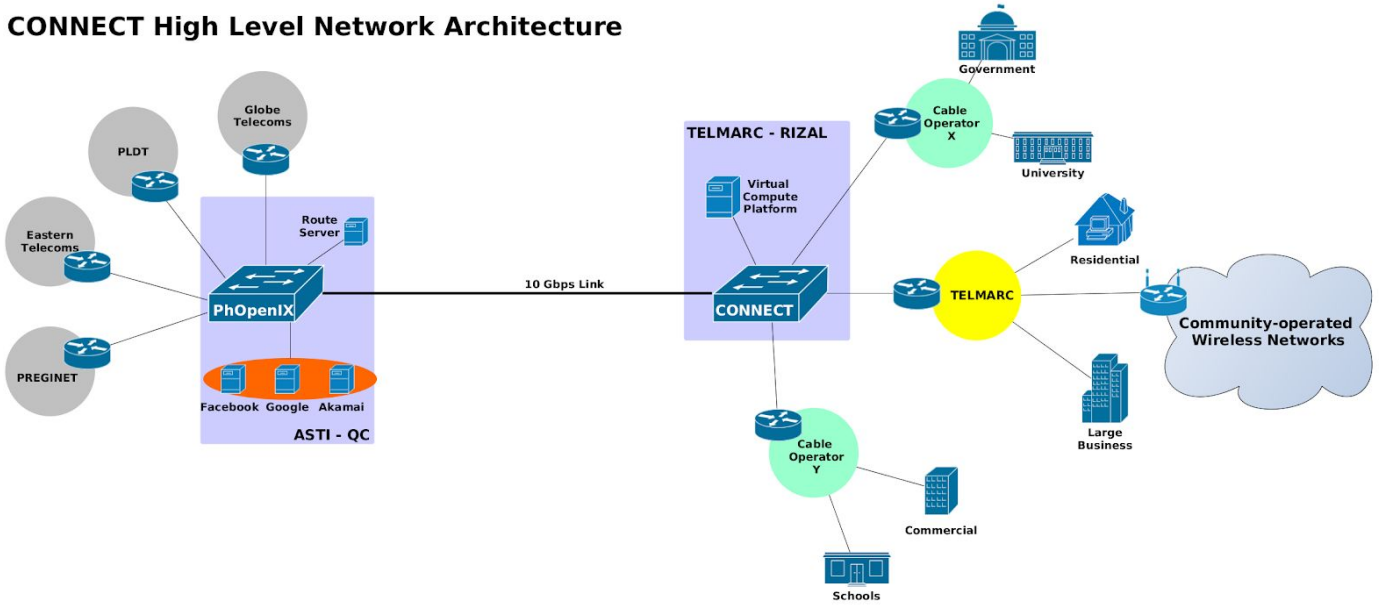

Figure 1. High level network architecture of the CONNECT project.

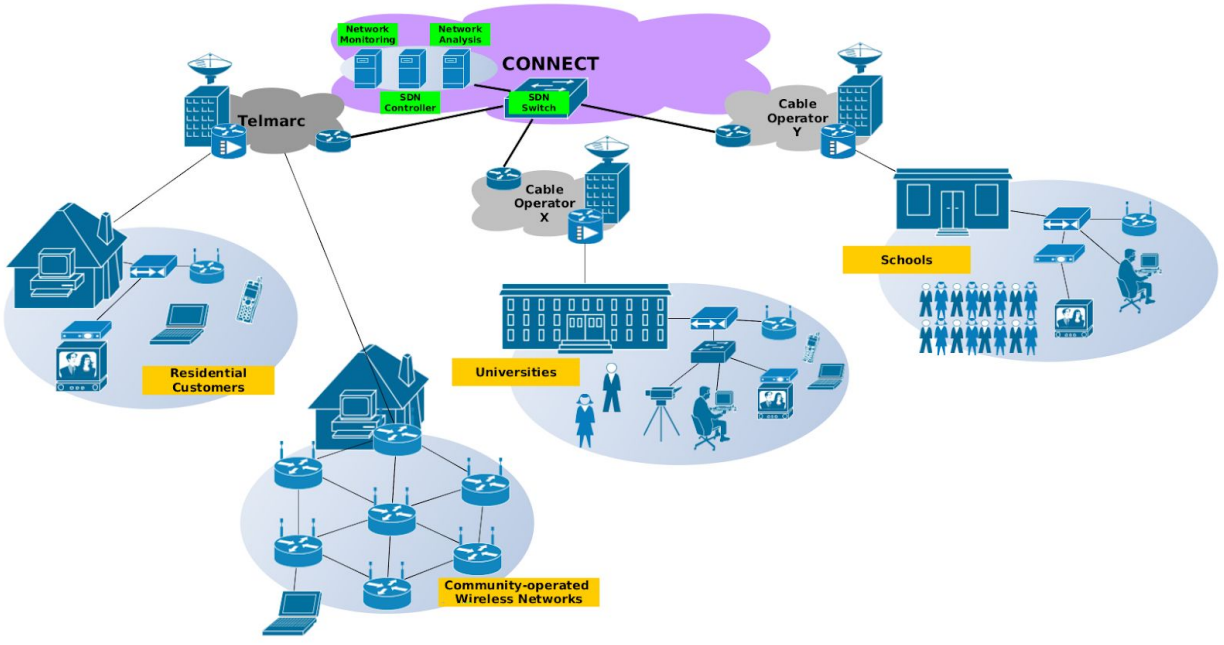

Figure 2. Detailed diagram of the CONNECT network architecture.

APPENDIX E - Letter of Support from Telmarc Cable Corporation

Please refer to the attached document named "**APPENDIX E - Telmarc Letter of Support.pdf**"