Luca Belli
Editor

Community Connectivity: Building the Internet from Scratch

Annual Report of the UN IGF Dynamic Coalition on Community Connectivity

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Preface by Bob Frankston

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Preface

Infrastructure for a Connected World

Bob Frankston

An interface is best when it disappears and the user can focus the problem at hand. In the same way infrastructure, is best when it can simply be assumed and becomes invisible.

With an invisible infrastructure as with an invisible interface a user can concentrate on their tasks and not think about the computer. Dan Bricklin and I chose to implement VisiCalc on personal computers that people could just purchase. This made VisiCalc *free to use*.

The reason the Internet has been so transformative is that it gives us the ability to ignore the "between" and focus on the task at hand or problem we are trying to solve. To use a website all you need to do is open the browser and type the URL (or, often, use an app), and it "just works". We take this for granted now. But when the web first burst onto the scene it seemed like magic. And, amazingly the web is effectively free-to-use because you pay for the connectivity totally apart from each website or connection.

If we are to extend this magic to connected things, aka the *Internet of Things*, we need to look behind the screen and understand the "why" of this magic.

In order to use the web, we just need connectivity. This worked well in local networks such as Ethernets where you can just plug in your computer and connect to any other such computer locally and thanks to interworking (AKA The Internet) this simplicity was extended to any other connected computer around the world.

Today I can connect to the web as I travel by having a cellular account and cadging connectivity here and there after manually signing up to websites (or lying by saying I read through an agree screen) and working past WiFi security perimeters. And we accept that oftentimes we're blocked.

If we are to truly support an “Internet of Things” we need to assure free-to-use connectivity between any two end points. Achieving this is a matter of technology and economics.

To take a simple example: if I’m wearing a heart monitor it needs to be able to send a message to my doctor’s monitoring system without having to negotiate for passage. No agree screens or sign-up routines. For this to occur we need what I call Ambient Connectivity – the ability to just assume that we can get connected. This assumption is the same as assuming that we have access to sidewalks, drinkable water and other similar basics all around us.

The principle challenge to achieving Ambient Connectivity today is economic. At present we fund the infrastructure we use to communicate in much the same way we paid for railroad trips by paying the rail companies for rides just as we pay a phone company to carry our speech. For a railroad operator, owning tracks is a necessary expense it bears so that it can sell the rides. It would not make sense to offer rides to places that “are not profitable to the railroad. It does not allow you to explore beyond the business needs of the railroads’ business model.

In this same way the telecommunications company owns wires (or frequencies) so that it can sell (provide) services such as phone calls and “cable”. It cannot make money on value created outside the network. This is why there is so much emphasis on being in the middle of “M2M” or a machine-to-machine view of connected things and treating them like dumb end points like telephones.

With the Internet we create solutions in our computers and devices without depending on the provider to assure they reach the messages’ correct destination in order. In this sense they are more like automobiles than railroad cars and we need policies more suitable to the infrastructure of roads and sidewalks.

A road is not merely a trackless railroad. We can drive across open fields or walk along paths if we choose. But communities pay for roads and sidewalks as common infrastructure to facilitate transit.

We do not have to collect a fee to pay for each step we take. More important, we do not have to stop passersby to assure they paid their sidewalk fee.

The traditional telecommunications business model allowed innovation only to the extent that a path-provider made a profit. This is at odds with an Internet where value is created outside the network and is totally decoupled from the particular wire that might be used to exchange packets. This is much like the value of a particular stroll being associated with, but not charged by, a particular square of pavement.

We can solve this by having the local community join together to pay for the common infrastructure based on the value realized by the community as a whole. This is a market based approach based on aligning incentives and value creation. It's what we do whenever we need to work together, be it sharing trash collection for an apartment house or paving the streets in a city.

The business of charging for "speech" (exchanging packets) limits innovation to what is profitable to a provider. It's as if you cannot get a street paved because it is not sufficiently profitable to the owner. Instead of thinking about providers we should think about communities creating their own solution. You and your neighbors join together to pay for the streets because you need them, not because a provider profits from them.

If your broadband connection goes out there is likely to be abundant connectivity nearby via WiFi or cellular or over another provider's broadband connection. But these may be unavailable because each one requires a separate billing relationship. It's like having water everywhere but not a drop to drink. And to add further injury – if your kids need to do their homework on the weekend they might have to wait days to get that connection back.

The shift from railroads to automobiles happened once we had engines that were light enough to use existing roads. Automobiles and trucks then generated a demand for more road capacity. Today we would say that the ability to travel freely created a viral demand for more capacity. Municipalities paid for roads to interconnect their communities. In 1919 Major Dwight D Eisenhower (http://goo.gl/foOZrw) recognized the need for a national highway system. Later, when he was President in the 1950s he was able to implement it.

Today the seeds of change can be found in every home and corporation where we have common connectivity. Your devices may share common facilities. This was not always the case. In 1995 the future of home networking was going to be the residential gateway and each time you added a computer you would get an additional recurring fee, just like adding another phone line or another set top box. I was at Microsoft at the time and wanted to put all my devices on a common network so I enabled windows to be "router ready" so that you only needed one connection to the rest of the world.

We take home networks for granted today but yet we still pay a separate monthly charge for each cell phone and other connected devices. We accept this model because few people understand the genius of the Internet and presume that we still need phone companies despite the success of Skype, WeChat, WhatsApp, and the many other offerings.

There is one Internet so why do we need multiple broadband infrastructures? Today's policies are akin to having ConEd or PG&E build a separate electric grid to compete with Eversource. In practice we get competition by using a common grid and choosing which electric power company we want to buy from. Unlike electricity we do not really "consume" data.

The Internet does **not** act like water pipes. You do not need twice the capacity for two computers. During the 100 seconds you are looking at a web page 100 other people download other pages without slowing you down. Carriers know this and benefit by reselling the same connections to 100 other people. Why cannot you get that same benefit by sharing with your friends and neighbors?

The good news is that we already have essentially unlimited capacity in place. It's as if we were looking ahead to Moore's law in 1970 and worried if we had enough silicon to meet our computing needs. Today's limitations on capacity are the result of policy and not technology. A single USB-C cable with very thin wires has 20 gigabits of capacity! With packets it does not matter if the signal is helped along by a wire or if we use wireless for a given segment. This allows benefit from the synergy across all technologies. We get a hint of this in the vast abundance of Wi-Fi compared with the limits of the cellular approach.

We are not limited by cost or technology.

The seeds of change exist. Today's home networks are DIY (Do It Yourself). Most companies and schools do their own networking. The Internet shows the power of DIO (Do It Ourselves). This is why I'm working to take home networking to the next level and turn apartment complexes and other spaces into connected communities. That provides the examples for larger communities such as campuses, office parks, and cities.

The Internet demonstrates the abundance and opportunity inherent in the existing infrastructure. Once we achieve recognition that the Internet is our new infrastructure we're then ready to reap the benefits of trillions of dollars in direct innovation. We get the benefits of connected health care, better environment monitoring and so much more.

About the Authors

Panayotis Antoniadis (M) is cofounder of the nonprofit organization nethood.org. He has an interdisciplinary profile with background on the design and implementation of distributed systems (Computer Science Department, University of Crete), Ph.D. on the economics of peer-to-peer networks (Athens University of Economics and Business), post- doc on policies for the federation of shared virtualized infrastructures (UPMC Sorbonne University), and an on-going collaboration with urban planners on the role of ICTs for bridging the virtual with the physical space in cities. He has played a key role in numerous European projects such as MMAPPS (Market Management of Peer-to-Peer Services), WIP (An All-Wireless Mobile Network Architecture), OpenLab (Extending FIRE testbeds and tools), EINS (The Network of Excellence in Internet Science), and he is the coordinator of the project COMPARE (Interdisciplinary of self- organization in practice). Panayotis is currently active in the organization of interdisciplinary events that aim to bring together researchers, practitioners, and activists from various fields around the participatory design of hybrid urban space with a focus on wireless and peer-to-peer technology.

Roger Baig Viñas received his degree in Automatics and Industrial Electronics Engineering (2000) and his degree in Industrial Engineering (2002) at the Universitat Politècnica de Catalunya (UPC), his MSc degree in Industrial Computing (2012) at Univeristat Autònoma de Barcelona (UAB) and his degree in Computer Engineering at the Universitat Oberta de Catalunya (2013). In 2011 he joined the Foundation for the Neutral, Free and Open Network - guifi.net as a researcher and currently is actively involved in two EU projects, Commons4Europe and Clommunity. He has been volunteering in guifi.net community network in 2006. There he has actively contributed in many aspects such as organising community events, promoting projects, giving talks, etc. and has gained a broad knowledge about community networks. His research interests are on mesh routing protocols and socio-economics and management of community networks. Currently he is the secretary of ISOC-CAT association.

Luca Belli, PhD is Senior Researcher at the Center for Technology and Society (CTS) of Fundação Getulio Vargas Law School, Rio de Janeiro, where he leads the 'Internet Governance @ FGV' project. Luca is also associated researcher at the *Centre de Droit Public Comparé* of Paris 2 University. Before joining CTS, Luca worked as an agent for the Council of Europe Internet Governance Unit; served as a Network Neutrality Expert for the Council of Europe; worked as a consultant for the Internet Society and as a Ph.D. researcher at Université Panthéon Assas (Paris 2). Luca is also the founder and co-chair of the Dynamic Coalition on Network Neutrality of the United Nations Internet Governance Forum, as well as the co-founder and co-chair of the IGF Dynamic Coalition on Community Connectivity and the Dynamic Coalition on Platform Responsibility. Amongst other publications, he has recently authored *De la gouvernance à la régulation de l'Internet,* edited by Berger-Levrault, Paris, and co-authored the *Net Neutrality Compendium*, edited by Springer.

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Melanie Dulong de Rosnay, PhD is a permanent researcher at CNRS. She leads the thematic cluster on the governance of the commons at the Institute of Communication Sciences.She is also a Visiting Fellow at London School of Economics and Political Science Department of Media and Communications for the period 2013-15, working on a monograph on the commons and distributed architectures. As associated researcher at CERSA (a joint unit of CNRS - University Paris 2), she was Creative Commons France legal lead between 2003 and 2013. Her research interests are the governance of the commons and the transformation of legal and technical regulation. She is currently involved as coordinator of legal workpackages of FP7 project P2PValue on commons-based peer-production and of the project ADAM funded by the French Agence Nationale de la Recherche on the legal, technical and socio-economical analysis of Distributed Architectures and Multimedia Applications. She co-founded in 2011 Communia, an international association on the digital public domain, which she currently chairs and represents at the World Intellectual Property Organization as a permanent observer. On behalf of Communia association, she is also a member of the European Thematic Network LAPSI 2.0 on Public sector information.

Nicolás Echániz is the President of AlterMundi. He has been involved in Community Networks for over a decade. Nicolás co-designed the multi-radio mesh network model that the AlterMundi network shares with communities willing to build their own communications infrastructure. He co-designed the LibreMesh firmware, the Librenet6 mesh tunel broker and the LibreMap mapping tool. He co-founded the Dynamic Coalition on Community Connectivity of the United Nations Internet Governance Forum. He is a regular speaker in connectivity-related events and he has authored numerous articles on Community Networks on printed as well as online media.

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Michael Graaf is an activist in the Right2Know Campaign’s telecommunications focus group and a Masters in I.T. candidate at the University of Cape Town’s Computer Science department, as well as research assistant at the BANG lab at the University of Western Cape, specifically collaborating with the Zenzeleni Networks initiative

Maureen Hernández recently graduated as Systems Engineer at the University of Los Andes (ULA), Venezuela. Maureen completed the CISCO CCNA curricula in the Escuela Latinoamericana de Redes founded by Ermanno Pietrosemoli in ULA and, in 2013, became an ISOC Fellow, attending IETF 83. Since then she has been focusing on wireless communications, she assisted to the WALC track for wireless networks for data transmission WIFI & WIMAX, in 2014 participated in the School on Applications of Open Spectrum and White Spaces technologies at the ICTP, started to experiment on spectrum sensing strategies with low cost devices, under the mentorship of Dr Arcia-Moret Andres. Thanks to the support of ISOC and APC, Maureen was able to debate spectrum sensing techniques at the roundtable on Community Networks during the last Dynamic Spectrum Alliance meeting. Maureen participated to the 2015 IGF as an ISOC Ambassador and to the South School on Internet Governance 2016 as an ISOC Next Generation Leader.

Guido Iribarren has been involved since 2012 in the elaboration of the AlterMundi community network model. Spanning a wide range of activities, dealing with the technical and social aspects of networks in Argentina and Latin America, while engaged in the LibreMesh firmware as a core developer, always strives to collaborate with other projects, and strengthen global links. Through this extensive experience helping communities around the world, has learned the needs and challenges faced by non-technical individuals from different cultures. Currently dedicated to the development of the LibreRouter, an open-source hardware mesh node designed according to community network requirements.

Paulo José Olivier M. Lara is Sociologist and Political Scientist, holds a masters in Sociology of Culture (UNICAMP) and is a PhD Candidate at Goldsmiths, University of London. Has a long involvement with culture and politics of media and is currently an associate of the LAVITS network.

Prof. Renato Lo Cigno has a long record of supervision and coordination of scientific projects, both at the national level and at the EU level, as well as some industrial projects. Just citing some of them, he coordinated the "PROFILE" Italian "PRIN" project (http://profiles.dit.unitn.it), dedicated to P2P networking "beyond file sharing". Profiles has been extremely successful with an outstanding scientific productivity. In the EU 7th framework project NAPA-WINE (http://napa-wine.eu), he coordinated the Work Package devoted to the P2PTV client study and development. NAPA-WINE was concluded with the highest appreciation of the PO and reviewers. The P2P system developed has been carried on as Open Source project: the Peer- Streamer P2P streaming platform (http://peerstreamer.org), which is used as starting base for Task T3.3. Recently the experimental project "Open Source P2P Streaming for Community Networks" (http://osps.disi.unitn.it) has been granted to Prof. Lo Cigno within the first Open Call of the CONFINE FIRE (FP7 grant 288535) Project. Additionally he coordinated an Activity (Smart Ubiquitous Content No. 12180) in 2013 within the EIT-ICTLabs.

Leonardo Maccari is Post-Doctoral research assistant at the Uni- versity of Trento, he received a degree from the Faculty of Computer Science Engineering in the Univeristy of Florence in November 2004 and a Ph.D. in the same institution in 2009. He has been involved in several research projects financed by the Italian Ministry of research (PROFILES Pro- ject), the EU FP6/7 programme (CRUISE NoE, NI2S3 Strep) the European Defense Department (ESSOR project) and private companies (Telecom Italia, Selex Communications, Siemens). He received a Marie Curie COFUND grant for the PAF-FPE project for the period 2011-2014. He is currently involved in the OSPS research project in the context of the CONFINE European project on Wireless Community Networks. He is an IEEE member and co-authored about 30 publications in refereed conferences and journals and book chapters. He is also among the authors of three patents. The focus of its research is network privacy and security in distributed environments such as wireless mesh/ad-hoc networks and peer-to-peer networks.

Maria Michalis, PhD is Reader in Communication Policy. She has a background in political science and interna- tional relations and has a PhD in Communication Policy. Her research interests are in the field of communication policy and regulation with a view to advance understanding of how technological, market, social, political and ideological changes impact upon and are negotiated through power relations and structures as manifested in policy and regulation, primarily in the European Union but within a comparative context. Her current research focus is on the interplay between the technological convergence of television and telecommunications/Internet, policy and business models. Her main research aim is to explain how transmission issues (including exchange and termination of digital traffic) shape access to content and audiences and, in turn, the user experience. In doing so, she points to the societal significance of the need to consider the interdependence between transmission and content. She is author of Governing European Communications (Lexington, 2007) and numerous book chapters and academic articles in journals. She was an invited expert to the European Social and Economic Committee's hearing on the European Commission's consultation on Connected TV (2013) and contributed to the VLV's submission to the same consultation. She is General Secre- tary (elect) of the International Association for Media and Communication Research (2012- present).

Leandro Navarro is associate Professor at the Computer Architecture Department of UPC. He received his Ph.D. from UPC in 1992. Research interests include the design of scalable and cooperative Internet services and applications. He coordinates the CNDS (Computer Networks and Distributed Systems) research group at UPC. He is responsible for the Erasmus Mundus Master in Distributed Computing at UPC. He coordinates the CONFINE IP project and the Erasmus Mundus Joint Doctorate in Distributed Computing (EMJD-DC), the national project P2PGrid (www.p2pgrid.info) and, among others, has participated in the FET Catnet, FET Catnets, SORMA, Grid4All FP6 EU projects. He is also council member of the Association for Progressive Communications (www.apc.org).

Cristiana Gonzalez is Ph.D. candidate at the University of São Paulo and researcher at Center for Technology and Society (CTS) of Fundação Getulio Vargas Law School, Rio de Janeiro. Before jining CTS, she was technical adviser at the Brazilian Internet Steering Committe (CGI.br), researcher at Brazilian Institute for Consumers Rights (IDEC) and project coordinator for the Association for Progressive Communications (APC). She worked for six years at GPOPAI – Research Group in Public Policies for Access to Information – at University of São Paulo.

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Carlos Rey-Moreno is a Post-Doctoral fellow in the Computer Science Department at the University of the Western Cape, South Africa. He received his PhD at Rey Juan Carlos University (URJC, Spain) in 2015. From 2007 to 2011, he was a researcher at the EHAS Foundation and URJC, working on the field of rural broadband telemedicine networks for developing countries, participating in the design and implementation of networks in Spain, Peru and Malawi. Since 2012, he is with the BANG group at UWC. He has been instrumental in the co-creation of Zenzeleni Networks, a telecommunications co-operative in one of the most disadvantaged areas of South Africa, whose sustainability plan has been the main focus on his PhD. That work also led him to acquire a deep understanding of the ICT ecosystem in South Africa and the issues around the high cost to communicate in rural areas of the country.

Ramon Roca i Tió is co-founder and the President of Fundació Privada per a la Xarxa Oberta, Lliure i Neutral guifi.net (The Foundation for the Open, Free and Neutral Network guifi.net). He has always been involved in IT social projects. In 2003 he had set up the first link of what few months later became the guifi.net community network. That wireless link was his proposal to overcome the lack of ISPs Internet supply in his village located in the rural area in the countryside of Catalonia. Immediately after, he started promoting his solution among his neighbours and started enhancing the Free Networks' model. Nowadays he is repeating that process with optical fibre, deploying it according to what he has called the FFTF model, i.e. Fibre From The Farm, a wordplay to stress that the Fibre deployment is made by active common people, From The Farm, instead of by the telcos, To To The Home. This model, called as "Bottom-up Broadband initiative" by himself, was one out of eight selected ideas of the The Digital Agenda Stakeholder Day on 25 October 2010. His professional career has always been related to international IT companies.

Ritu Srivastava has over 10 years of rich professional experience in ICT development, managing programmes and projects at different stake-levels of competency. She has been actively entailed with Information, Communication and Technology (ICT) from the last 8 years. Her areas of interest, activity and research are Information Communication and Technology (ICT) at the grassroots level, internet governance, environmental issues, community development, gender & access, open spectrum policy issues, internet governance, etc. Presently, she is assisting Delhi based non-profit organization, Digital Empowerment Foundation (DEF) in various ICTD related projects and responsible for project design, ideation, implementation, leading policy meetings, fun-raising proposals, partnership forging, event guidance, workshops management and organizing. She also represented DEF in various international conferences.

Félix Tréguer is a Post-Doctoral researcher at ISCC for the netCommons project on European community networks. He is also junior researcher at CERI-Sciences Po for the UTIC project where he works on communications surveillance by law enforcement agencies. He is also a founding member of the digital rights advocacy group La Quadrature du Net. Research areas: civil rights online, censorship and surveillance, technical and legal resistance. Approaches: law, political theory, history and sociology of law.

Diego Vicentin, MA and PhD in Sociology (UNICAMP), has experience with mobile cellular and internet networks standards development and its social implications. Associate of the CTeMe (Knowledge, Technology and-Market) research group at UNICAMP.

Contents

1. Framing the Community Network Debate

Luca Belli and Cristiana Gonzalez

This report is structured in two sections analysing (i) the architecture, governance and policy features of Community Networks (CNs) and (ii) subsequently exploring a variety of CN experiences, fostering connectivity around the world.

1.1. Community Networks: Governance, Policy and Regulation

The first part of this report encompasses four analyses defining CNs' underlying structure and conceptual theory; exploring regulatory barriers; and bringing possible solutions for the main policy, regulatory and governance challenges.

In their paper on "Fostering Connectivity and Empowering People via Community Networks: the Case of AlterMundi," Luca Belli, Nicolás Echániz and Guido Iribarren stress that, given that 4 billion people still lack access to the Internet, the traditional model of Internet access provision should not be necessarily considered as the most efficient one. Therefore, alternative models such as CNs should be experimented and analysed, in order to test their feasibility and should be encouraged, in case they prove viable and scalable. CNs foster a particularly interesting approach to connectivity, due to their peculiar features as alternative bottom-up initiatives, based on community-driven infrastructure development, which may prove efficient to bridge existing digital divides. The authors stress that, differently from traditional networks, CNs directly engage users that may be active participants in the network design, deployment, operation, and maintenance. Analysing the core elements of CN, the authors suggest that although in the past the establishement of CNs has been challenging, at present, CNs may be relatively easy to develop, exploiting the exisiting knowledge. However, the success of such bottom-up and community-driven efforts depends on a variety of factors, exceeding the mere technical sphere. Belli, Echániz e Iribarren consider some essential policy and governance challenges and, subsequently, analyse an example of successful community-networking experience, the AlterMundi network model. Providing insight on the inception, evolution and fundamental features of the AlterMundi Network, the authors stress that alternative models may not only be successful in connecting unconnected communities but they can also empower local stakeholders, creating a new local digital ecosystem and allowing local communities to become the true protagonists of the connectivity growth.

In "A commons-oriented framework for Community Networks" Leandro Navarro, Felix Freitag, Roger Baig and Ramon Roca introduce a unique framework for the comparative analyses of community networks instances, mostly driven by Elinor Ostrom's commons theoretical principles. First, the authors review and partially re-define the concept of commons in the context of digital networks infrastructures. Subsequently, the article provides a general framework for the comparative analysis of different CN instances in an attempt to set a "reference conceptual architecture" that can help understanding different organisational models and their implementation. Particularly, the authors analyse the resilience and sustainability in a common property regime (CPR), its incentives and compensation mechanisms and provide a list of CNs around the world, followed by a detailed analysis of commonalities and differences. As the authors highlight, diversity makes a difference, and local CNs are able to created local institutions or organisational structures adapted to local conditions and needs, with different levels of sophistication and varying from starting points, goals, strengths and weaknesses, as well as levels of development and structuring. However, form the analysis it emerges that the power of CNs is not limited to the local realm. The complexity and challenges around the CN environment suggest that as the networks grow, they tend to form federated structures. Importantly, such "second-layer organisations" allow to aggregate smaller and local initiatives and enjoy the benefits of scale in sharing knowledge, sometimes also governance, services, infrastructure, and become a visible actor to have a dialogue with governments, regulators or other agents as a sector or collective.

In June 2016, the netCommons.eu project organised a workshop in Barcelona (Spain) to share views and discuss how public administrations, citizens and enterprises can strengthen ties amongst them to contribute to the growth of CNs. In their contribution of this report, Leandro Navarro, Roger Baig, Ramon Roca Renato Lo Cigno, Leonardo Maccari, Panayotis Antoniadis, Maria Michalis, Melanie Dulong de Rosnay and Félix Tréguer reflect on the advancement and main lessons learned during the netCommons.eu workshop. Notably, based on the experience and the work done so far by various CNs in Europe, the paper on "Efficient collaboration between government, citizens and enterprises in commons telecommunication infrastructures" attmpts to expand knowledge about multistakeholder collaboration with regard to CNs, while identifying specific lines of action to make them more efficient in the future. These challenges are analysed and discussed successively from the point of view of governance, presenting the theoretical framework and a variety of organizational arrangements beyond the traditional commercial model; regulation, in order to provide a better understanding of the legal issues surrounding CNs; and CN implementation. Although further work is required to develop universal ideas and generic mechanisms in the light of the local specifics, the authors believe that coordination mechanisms among private and public organisations and citizens can help to accelerate the development of sustainable networking infrastructures, for the benefit of all parts and society in general. Different organisational models, cooperative and competitive schemes, coordinated and regulated by public entities, can flourish and allow commercial and community operators to develop and ensure they can best participate in the digital society.

The first part of this report is closed by Federica Giovanella's paper on "Community Networks: Legal Issues, Possible Solutions and a Way Forward in the European Context." Particualrly, Giovanella focuses on the issue of tort liability, with regard to three different actors: CNs users; Internet Service Providers, for the case of shared Internet connection; and CNs themselves, describing different situations to which civil liability could or should be applied. As the analysis demonstrates, the inherent structure of CNs seems irreconcilable with the aims of current legal framework for tort law in Europe. Its distributed character often implies the fragmentation of conducts: a single conduct can be ascribed to a high number of different users' machines, and most communities have neither written norms regulating relations amongst users, nor central authority. If, on the one hand, the possibilities of identifying wrongdoers are diminished, on the other hand, offering no legal protection for victims, implementing an identifying system could have a chilling effect on freedom of expression. The author therefore seeks to indicate possible steps to be taken to allow a reconciliation between CNs' prosperity and the needs of law-enforcement. For instance, Giovanella suggests that lawmakers should consider existing CNs' tools, or "soft regulatory tools", as a starting point and encourage the adoption of more detailed codes of conducts that could turn into an informal monitoring system implemented by users. This would depend on a careful study of the functioning of the communities and of their social norms and the effectiveness of such system would have to be tested. In any case, as Giovanella argues, a part from the questions related to liability, policymakers should start considering the adoption of regulations that could foster CNs. In light of the fact that CNs are spreading all over the world, there is no doubt that specific policy actions should be considered in order to allow and promote the experimentation and eventual prosperity of such networks, including in developing countries.

1.2. Do It Yourself: Creating Connectivity around the World

The second part of this report explores a wide range of CN examples, stressing the existence of an ongoing CN movement, which is successfully spreading on a global scale.

In her paper on “A network by the community and for the community” Ritu Srivastava argues that CNs play a pivotal role in bridging existing digital divides in India, fostering connectivity and empowering individuals and communities, particularly creating new opportunities for individuals living in remote areas. Notably, the paper focus on Wireless Community Networks (WCN) or Community based Internet Service Provider (C-ISP), which are such networks whose infrastructure is developed and built by small organisations and community members by pooling their resources. These networks are managed, operated and owned by community members. Srivastava highlights that CNs offer affordable access to the Internet while strengthening the local community. These networks are meant to provide last mile access from the village council level to the household level. Srivastava highlights that, to provide last mile access, the government of India has proposed various action plans including the National Optic Fibre Network (NOFN) under its umbrella vision, Digital India. As the author argues, the challenge is not only limited to laying wired infrastructure but also demands to consider how to connect a country where limited bandwidth is available. This implies a need for a decentralised model, highlighting the existence of various patterns of using ICTs and alternative solutions to foster sustainable connectivity and create sustainable smart villages. In this perspective, the author explores the “wireless for community programme,” promoted by the India based Digital Empowerment Foundation, whose purpose is to provide affordable, ubiquitous and democratically controlled Internet access in rural regions of the country. Conspicuously, Srivastava notes that the wireless for communities programme is enabling communities’ economic development, reducing poverty and encouraging civic participation, while creating smart villages around the country. The author investigates the efficacy of creating WCN, C-ISP and Rural Internet Service Provider (RISP) and explores the possibility of policies, which could help in creating widespread information infrastructure for the still-unconnected populatins of the country.

In their paper on a "Map of the Community Network Initiatives in Africa," Carlos Rey-Moreno and Michael Graaf provide a unique perspective on CNs in the African continent. As Internet infrastructure built by citizens for the benefit of their communities, CNs have grown consistently and attracted considerable attention in recent years. In particular, the authors stress that a growing number of voices is proposing CNs as a potential solution to provide affordable access in areas where the market is failing to do so. However, none of the CNs usually considered as examples, such as guifi.net, Rhizomatica or the Digital Empowerment Foundation, to name a few, come from Africa, where access to affordable communications is lacking in most places. Rey-Moreno and Graaf attempt to identify the reasons behind this gap by providing the first map of the CNs deployed in the African continent. CNs have been identified via web search and interviewing people directly or indirectly involved with their development. Results include the identification and profiling of 37 initiatives in 12 different countries, out of which 30 are currently at least partially active. Results show that 60% of these networks are located in one single country, South Africa, while only 1 (and not active anymore) was identified in the whole of Northern Africa. Additionally, in contrast with the common definition of CNs being essentially decentralised networks, in the African continent, most networks (82%) have less than 30 nodes, and have been either funded and/or bootstrapped externally. Only Wireless User Groups in South Africa fits into the definition of a large scale and decentralised CN. Bearing in mind the many particularities of different contexts, the results put forward by Rey-Moreno and Graaf are a necessary and valuable first step to start understanding the CN movement and allow such movement to have a greater impact in Africa.

Subsequently, in their paper on "Beyond the last mile: Fonias Juruá Project – an HF digital radio network experiment in Amazon (Acre/Brazil)," Francisco Caminati, Rafael Diniz, Anna Orlova, Diego Vicentin and Paulo Lara analyse the possibility to utilise digital radio on High Frequency (HF) to expand information and communication infrastructure. Notably, the authors present the experience of the "Fonias Juruá" project, which applies digital radio on HF to provide information and communication infrastructure to a rural Amazon community, which is underserved by regular/commercial networks. The authors analyse the historical and political background of the project and describe the novelty of the technical solution that is being developed. The beyond-the-last-mile image is evoked not only to acknowledge the material conditions of the lack of Internet connection in a particular locality but mostly to propose a critical framework to address and question the paradigm of inclusion as an imperative for the underserved global south. Notably, Caminati *et al.* highlight the centrality of the spectrum governance in order to properly debate CNs, while allowing to explore the potential of digital radio technologies as network solutions. The experience of the “Fonias Juruá” project is contextualised within relevant historical and contemporary initiatives in Latin America allowing to comprehend the different facets – local/community; popular; public; free; illegal/subversive – of radio transmissions, Internet “appropriation” and direct interventions with regard to spectrum governance.

Lastly, in her paper on “*Caracterización de los espacios en blanco del espectro radioeléctrico en la banda UHF en países emergentes: Caso de estudio del Estado Mérida*” (The Characterisation of the White Spaces Spectrum bands in emerging countries: the Case of Mérida State), Maureen Hernández explores the use of White Spaces (TVWS) as a solution to the shortage of spectrum and the expansion of connectivity in remote areas. TVWS are spectrum bands left unused by TV broadcasters, due to the transition from analogue to digital television or simply because in certain regions TV operators do not see a return on investment. Therefore, these frequencies are available for use. However, Hernández highlights that monitoring technique must be performed in order to declare that a portion of spectrum is underused. In this perspective, the author performs a census of the spectrum frequencies between 300 MHz and 900 MHz, which belong to the Ultra High Frequency band. The measurement are undertaken exploiting low-cost devices so that such exercise can be easily replicated in developing countries, where the possibility to utilise unexpensive technology is an essential requirement. The author offers a measurement framework, developed through an empirical approach, demonstrating that it is possible to make an organised and structured census of spectrum bands with the aim of providing insight into the state of spectrum. As argued by Hernández, the possibility to undertake such measurement plays an instrumental role, in order to justify the use of TVWS for the deployment of CNs as well as for cognitive-radio use.

Part I
Community Networks: Governance, Policy and Regulation

2. Fostering Connectivity and Empowering People via Community Networks: the case of AlterMundi

Luca Belli, Nicolás Echániz and Guido Iribarren

Abstract

In this article, we argue that, given that 4 billion people still lack access to the Internet, the traditional model of Internet access provision should not be necessarily considered as the most efficient one and, therefore, other alternative models should be experimented. We explore community networks (CNs) as an alternative bottom-up approach, based on community-driven infrastructure development, as a substitute to the classic top-down operator-driven paradigm. We stress that, differently from traditional networks, CNs directly engage users that may be active participants in the network design, deployment, operation, and maintenance. In the first part of this paper, we analyse the core elements of CNs, pointing out that, although such networks may be relatively easy to develop, their success depends on a variety of factors, exceeding the mere technical sphere and leading us to consider some essential policy and governance challenges. Subsequently, in the second section of this paper, we examine an example of successful community-networking experience, the AlterMundi network model, deployed in José de la Quintana and the surrounding region, in Argentina. Providing insight on the inception, evolution and fundamental features of the AlterMundi Network, we stress that alternative models may not only be successful in connecting unconnected communities but they also empower local stakeholders allowing them to become the true protagonists of the construction of connectivity.

2.1 Introduction

In order to understand the value of community networks and their disruptive potential it is essential to understand that the traditional way of providing Internet access, based on the existence of (large) access providers and individual access subscriber, is not the only way to foster Internet connectivity. Furthermore, such "traditional" model should not be necessarily considered as the most efficient, given that, at present, 4 out of 7.5 billion people still lack access[1] to the Internet.

Although consensus has crystallised with regard to the benefits of connectivity (McKinsey 2011; OECD 2012; Guerriero 2015), it seems obvious that such benefits are still distributed in an uneven fashion and the majority of the world population, especially in least-developed countries, is still off-line. (ITU 2015) The current situation, together with the recent inclusion of "universal and affordable access to the Internet in the least developed countries"[2] amongst the UN Sustainable Development Goals, leads us to ponder whether alternative approaches to those experimented so far are available and what are the conditions that may facilitate such alternatives. The Internet was conceived as a networking technique able to foster an open and distributed communication environment, in which multiple approaches could and should be experimented in order to achieve universal connectivity. Therefore, it seems desirable not to limit our comprehension of connectivity to the above-mentioned "traditional" model but rather to explore the existence of suitable alternatives.

In this paper, we briefly explore community networks (CNs) as an alternative bottom-up approach, based on community-driven infrastructure development, as a substitute – or, at least, a complement – to the classic top-down operator-driven paradigm. CNs are crowd-sourced networks built by citizens and (generally non-profit) organisations pooling their resources and coordinating their efforts to build network infrastructures. (Baig *et al.* 2015) Differently from traditional electronic networks, which are based on top-down control of the network and centralised approach, (Saldana *et al.* 2016) CNs rely on the development and use of independent infrastructure, based on a distributed or "mesh" architecture, operating autonomously from pre-existing infrastructure. (Flickenger 2002) Hence, differently from traditional networks, CNs directly engage users that can be active participants in the network design, deployment, operation, and maintenance. Such community-driven initiatives seem particularly inter-

1 See http://www.internetlivestats.com/internet-users/ as well as http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

2 See Sustainable Development Goal n° 9. http://www.globalgoals.org/global-goals/innovation-and-infrastructure/

esting to explore, due to their potential to provide Internet connectivity to unconnected communities in remote areas, while fostering the active engagement and empowerment of community members. Indeed, CNs inevitably empower local stakeholders that are essential players within the governance structures on which the management of the common infrastructure is based. In this sense, we argue that CNs can prove beneficial to expand Internet infrastructure and encourage digital literacy, while creating new working opportunities for those individuals and organisations that undertake their management. (Baig et al. 2016) Furthermore, existing examples of CNs suggest that such initiatives may be valuable for capacity-building purposes, improving not only access to knowledge but also the production and circulation of local content and services.[3] Hence, CNs may play an important role in promoting freedom of expression and triggering a virtuous circle of knowledge-and-innovation creation and sharing amongst CNs participants.

In the first part of this paper, we analyse the core elements of CNs, pointing out that, although such networks may be relatively easy to develop, their success depends on a variety of factors, exceeding the mere technical knowledge and leading us to consider some essential policy and governance challenges. Subsequently, in the second section of this paper, we provide a concrete example of successful community-networking experience, analysing the development, evolution and fundamental features of the AlterMundi[4] network model, deployed in José de la Quintana and the surrounding region, in Argentina.

2.2 Fundamental features of community networks

Over the past decade, CNs have been springing up in both developing and developed countries, becoming a credible solution to bring people online. As pointed out by Saldana *et al.* (2016), CN are networks "in which any participant in the system may add link segments to the network in such a way that the new segments can support multiple nodes and adopt the same overall characteristics as those of the joined network, including the capacity to further extend the network." Besides the AlterMundi network that will be examined in section 2, notable examples of CNs include Guifi.net,[5] covering the entire Catalonia region in Spain, Freifunk[6] in Germany,

3 See below section 2.2.1

4 See http://www.altermundi.net/

5 See http://guifi.net/en/node/38392

6 See https://freifunk.net//en/

the Digital-Empowerment-Foundation[7] networks in India as well as an ample range of Community Fibre Network (CFN), which are stimulating a CFN movement, gaining increasing momentum in the US.[8] Such diversity suggests not only the feasibility but also the sustainability of CNs, which are deployed and managed by local communities in order to satisfy their connectivity needs. As such, community engagement turns out to be an essential component to make CNs both technically and economically sustainable,[9] fostering the growth of the network, which depends on the willingness of community members to join the initiative.

2.2.1 An Alternative Approach to Connectivity

CNs are usually based on wireless technology, involving the use of low-cost Wi-Fi equipment – based on the IEEE 802.11 family of standards – and the exploitation of unlicensed 2.4 GHz and 5 GHz spectrum bands. Licensed spectrum bands can only be utilised by the entities holding the licenses, be they business entities, for commercial purposes, or governmental actors for public-administration purposes. On the other hand, unlicensed spectrum can be freely used with no need for license and for a variety of purposes, such as the development of Wi-Fi networks. Notably, since the early 2000s, wireless CNs have been developed to provide entire communities with Internet connectivity, for minimal hardware cost, exploiting 802.11b/g/n specification and easy-to-find radio equipment to extend Wi-Fi signal to several square kilometres. (Flickenger 2002) CNs basically exploit point-to-point links to provide Internet connectivity where this is not available; point-to-multipoint links to share connectivity, thus setting up access points; and peer-to-peer nodes allowing CN participants to impart and receive data as long as they stay within signal range[10]. Although CNs are commonly based on the provision of connectivity via Wi-Fi technology, CN infrastructure may also integrate the exploitation of optical fibre, for instance through the development of condominium fibre infrastructures. However, differently from wired infrastructure, CNs can be based mainly on wireless technology, thus greatly reducing the cost of deployment and maintenance in comparison to so-called "last-mile" fixed connections.

7 See http://defindia.org/access-infrastructure/

8 See https://muninetworks.org/communitymap

9 As pointed out by Crabu *et al.* (2015) technical sustainability is provided by a design allowing to scale-up the network and maintaining connectivity as the user-base increases, while economic sustainability is the capacity to maintain a positive economic balance, crowd-sharing the infrastructure costs.

10 The WiMAX standard 802.1 has been designed to extend signal range, allowing the provision of wireless Internet access across greater distances.

Both Wi-Fi and fibre-based CNs rely on community-driven efforts and aim at creating new infrastructure that can be entirely autonomous from the existing one, which is managed by traditional operators. Indeed, as argued by Bar and Galperin (2004), one of the main reasons leading to the development of CNs is the emergence of "bottom up dynamics [...], where multiple network players are independently pursuing the development of wireless infrastructure." In such context, CN participants – the ones that the traditional paradigm for Internet access provision considers as mere customers – undertake an active role operating and maintaining the CN, while traditional operators are not needed anymore to provide Internet access to individuals, but rather undertake a function of backbone-connectivity providers, in order to connect the various CNs.

Such model has proved to be well suited to meet the needs of small communities where CN participants have a say in the CN management and can directly perceive the benefits of connectivity. Notably, the side effects of the community engagement in the construction and maintenance of the new infrastructure are the promotion of the local (digital) economy and digital inclusion. However, it is important to note that CNs are not limited to small realities. On the contrary, existing examples such as Guifi.net and the Freifunk network show that these initiatives may be scalable and cover quite extended geographic areas. Furthermore, it seems important to stress that such initiatives do not imply a lower level of quality. Indeed, CN members may be keen and capable to deploy state of the art technologies that cannot only compete but also have much higher performances than traditional providers' networks, particularly in rural areas.[11] Besides facilitating community cohesion, the bottom-up dynamics at the core of CNs incentivise the experimentation of innovative mechanisms allowing the participation of local-community members into the new socio-technical network established by and through the CN. Hence, although CNs were initially born to provide a solution to existing digital divides, their evolution has prompted the exploitation of connectivity to create new socio-economic environments in a bottom-up fashion.

In In this sense, CNs may be an effective stimulator of Internet generativity,[12] reinforcing Internet users' peculiar role of prosumers, *i.e.* both producers and consumers of content and applications. In fact, CNs seem to foster a particular type of generativity, based on the collaborative elaboration and implementation of new applications and services. As an instance,

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11 See *e.g.* Altermundi. Multiple hop mesh performance with multi-band dual-radio routers. https://blog.altermundi.net/article/multiple-hop-mesh-performance-with-multi-band-dual/

12 Generativity is generally referred to as "a system's capacity to produce unanticipated change through unfiltered contributions from broad and varied audiences." See Zittrain (2008), p. 70.

Guifi.net participants have jointly elaborated and autonomously deployed a variety of tools aimed at facilitating the life of the CN participants, such a maps[13] or shared planning tools. Likewise, the participants to the Athens Wireless Metropolitan Network have created a variety of services spanning from messaging services, such as e-mail servers and instant messaging, to search engines, broadcasting of music and video or community fora.[14] Such environment seems to create favourable conditions to let the community take full advantage of connectivity and develop their local socio-economic environment. A further example in this regard is the idea of a "CommunityCoin," *i.e.* a cryptocurrency based on block-chain technology that can be used by CN members to purchase goods or services from other participants, which has been experimented in Guifi.net with the purpose of rewarding the participation of members in the CN. (De Filippi & Tréguer 2014) Furthermore, CNs offer the possibility to improve the quality and efficiency of public services via the development of public e-services.

The organisational models on which CNs are developed and run can empower the members of local communities in a variety of manners. Local stakeholders – which may be public administrations, NGOs or any group of individuals – can gain the capacity to become new connectivity providers but may also establish alternative business models,[15] creating new occupation and promoting the development of new economic ecosystems, in the public interest of local communities. This is, indeed, the great benefit of CNs. Besides bridging digital divides, CNs represent a great generator of opportunities because their ultimate goal is not merely to foster communication in a traditional perspective, but rather to foster the quintessence of connectivity, *i.e*. the possibility to create any kind of cooperative relations in order to organise individuals and potentially generate social, economic and technical innovations.

The originality of the CN models is therefore to encourage a socio-economic organisation, based on the consideration of the CN as a common-pool resource[16] (Baig *et al.* 2015) that may be exploited to enhance the organisation and welfare of local communities. In this regard, CNs can be seen as a resource whose utility improves together with the number of users joining the network and cooperating to the creation of connectivity

13 See http://guifi.net/guifi/menu/stats/growthmap?id=1 as well as http://guifi.net/es/node/23068/view/distancesmap

14 See http://www.awmn.net/content.php?s=b67a85baa6c5b-433fb1f024839f43554

15 The Guifi.net business model, for instance, has generated an annual turnover evaluated at several million euros and has created dozens of direct jobs. See Baig *et al.* (2016)

16 For a thorough analysis of the concept of "common pool resource,"see Ostrom (1990).

and generation of new content and services. As pointed out by Ostrom (1990), effective governance mechanisms are key to maintain the common-pool resources sustainable in the long term, with particular regard to a system's capability to be productive and operational in the long-term. More generally, a sustainable system is able of meeting the needs of the existing community without compromising the ability of future members of the community to meet their own needs. (UN WCED 1987) Ergo, such sustainability depends on the definition of shared principles and policies that effectively frame the distribution of costs and benefits related to the elaboration and implementation of CNs and are implemented through efficient governance and technical architectures. Furthermore, public policy and regulation may have a direct impact on CNs' capability to be sustainable.

In light of the above, it is important to stress that, to be sustainable, CN may face both technological problems, related for instance to network architecture and network coverage, but also regulatory challenges, related to telecom regulation as well as to intermediary liability. The technical aspects will be explored in Section 2.3 through a concrete case study, analysing the evolution of the AlterMundi network, which lends itself very well to exemplify the challenges that CNs may encounter in rural areas. The policy and regulatory challenges will be briefly explored in the section below.

2.2.2 Public Policy and Regulatory Challenges

Public policies and regulations may facilitate or hinder the development of CNs. In this perspective, two complementary facets should be considered. On the one hand, the impact upon CNs and CN participants of policies and regulations such as spectrum regulation or intermediary liability legislation.[17] In this sense, it is also important to stress that the possibility to establish and operate CNs may be directly affected by policies elaborated at international, national or local level alike. On the other hand, self-regulatory tools and contractual agreements may offer useful solutions to efficiently organise the CN governance as well as the rights and obligations of the CN participants.

The success of CNs depends on a variety of factors amongst which organisational features, such as proper management or capacity building of CN participants, but also on the existence of a favourable policy environment. As an instance, legislation establishing data-retention obligations for network operators or imposing the responsibility to secure one's connection to network users may jeopardise the development of CNs, where the CN "opera-

17 See Chapter 5 of this Report.

tor" can be an undefined community and users may not be easily identifiable. (Giovanella 2015) Notably, many CNs have been developed paying particular attention to anonymity, for instance allowing users to continuously change their IP address that, differently from traditional networks, are not listed or registered by operators. Although such anonymity may be seen as a solid guarantee for freedom of expression, it is also important to stress that it can make it very hard to apply legislation regarding a variety of issues, spanning from copyright violations to child-pornography and, therefore, reduces the law-enforcement agencies' propensity for CNs. However, such problems may be mitigated through the development of solid self-regulatory mechanisms to which CNs users should subscribe and abide, such as the Compact for a Free, Open & Neutral Network[18] (FONN Compact) or the Pico Peering Agreement.[19] Such self-regulatory documents formalise the interaction between CN owners of network nodes and CN users, thus setting shared principles and making explicit CN participants' rights and duties. Tools like the FONN Compact and the Pico Peering Agreement turn out to be more than mere agreements, enshrining a true "social contract" fostering trust amongst the CN participants (Maccari & Bailoni 2015). Importantly, the principles and rules emerging from such bottom-up social contracts may be turned into concrete contractual provisions that CN participants can commit to respect.

On the one hand, the FONN Compact is based on shared fundamental principles according to which CN participants have:

- the freedom to use the network for any purpose as long as you do not harm the operation of the network itself, the rights of other users, or the principles of neutrality that allow contents and services to flow without deliberate interference;
- the right to understand the network and its components, and to share knowledge of its mechanisms and principles;
- the right to offer services and content to the network on your own terms;
- the right to join the network, and the obligation to extend this set of rights to anyone according to these same terms.

On the other hand, the Pico Peering agreement is based on the recognition and mutual respect of:

- neutral, *i.e.* non-discriminatory, and free transit of data across the network;
- open communication, allowing peering;

18 See https://guifi.net/en/FONNC

19 See http://www.picopeer.net/PPA-en.shtml

- best effort delivery, *i.e.* no guarantee of quality of service;
- the possibility for the node's owner to establish 'acceptable use policy' as long as it does not contradict the abovementioned points.

In addition, national and international policies and regulations concerning issues such as spectrum allocation may have a direct impact on CN development. Indeed CNs critically rely on the availability of unlicensed spectrum or unused spectrum bands such as TV white spaces[20] as a critical resource for inexpensive connectivity through the use of wireless technology. In this perspective, rules favouring the use of unlicensed or unused spectrum bands are key to allow the development of wireless CNs and bridge digital divides, connecting marginalised (and frequently rural) areas. Conversely, scarcity of spectrum may challenge the stability of CNs and the services they provide. For this reason, existence of unlicensed spectrum and the possibility to utilise dynamic spectrum solutions[21] to exploit TV white spaces play a key role in facilitating the deployment and well-functioning of CNs. (Saladana *et al.* 2016)

In this sense, CNs rely on national regulators' willingness to maintain part of the spectrum unlicensed, rather than entirely licensing it to private providers, and to allow secondary use TV white spaces. Furthermore, the deployment of wireless CNs is clearly incentivised by regulations allowing municipalities to actively use unlicensed spectrum and spectrum reserved for public safety for wireless CN development.

2.2.3 The importance of Public Stakeholders

It is important to stress that, although CNs usually emerge from bottom-up efforts driven by individuals or NGOs, local governments play a key function with regard to facilitating the development of CNs. Notably, Gillett

20 The term "white spaces" is generally used to describe "VHF and UHF television frequencies [...] to be exploited on a secondary use basis. There are two dominant standards for TV White Space communication: (i) the 802.11af standard [IEEE.802.11AF] -- an adaptation of the 802.11 standard for TV White Space bands -- and (ii) the IEEE 802.22 standard [IEEE.802.22] for long-range rural communication." See Saldana *et al.* (2016).

21 In the locations where licensed users do not exploit their UHF and VHF television frequencies, CN users may act as secondary users, making use of the unexploited TV White Spaces. In order to do so, Saldana *et al.* (2016) highlight that specific equipment "is required to detect the presence of existing unused TV channels by means of a spectrum database and/or spectrum sensing in order to ensure that no harmful interference is caused to primary users. In order to smartly allocate interference-free channels to the devices, cognitive radios are used that are able to modify their frequency, power, and modulation techniques to meet the strict operating conditions required for secondary users."

et al. (2004) have identified four categories of actions that local governments can promote and implement, depending on the different roles that they can undertake.

- Public administrations may act as a network user, thus stimulating the development of connectivity and deployment of CNs from the demand side. Furthermore, local governments can develop policies aimed at stimulating or aggregating connectivity demand.

- Public administrations may act as policymakers, designing local policies in a way that promote the development of CN as an ancillary effect of other rules concerning, for instance, urban planning, road-development or building-construction codes.

- Public administrations may be a financier, subsidising CN development, for instance, providing equipment grants, tax incentives for CN development or maintenance.

- Public administrations may be an infrastructure developer, directly providing or managing one or more components of network infrastructure. In this sense, besides putting in place public-interest initiatives such as offering Wi-Fi access in public buildings or parks, local governments may generate revenue via the development and management of CNs for a fee.

Local governments acting in their various capacities may largely benefit from multistakeholder partnerships – particularly encouraging the co-operation with civil society and academic actors when private operators lack economic motivation to invest *e.g.* in a rural area – both in the conception, the development and the maintenance of the CNs. It is also important to stress that the different levels of the public administration should co-operate building their policies in synergy. As an instance, national policies should neither prevent local governments from using unlicensed spectrum for CN development purposes, nor restrict municipalities' capacity to provide – or collaborate in the provision of – Internet communication services. Notably, restrictions on municipalities may jeopardise their capacity to compete with operators for the provision of connectivity, thus hindering the possibility that local governments positively contribute to the connection of unconnected communities. Furthermore, it seems reasonable and desirable that national policies foresee that local administrations involve the local communities through open consultation aimed at defining the conception as well as the implementation of CNs.

Lastly, it is important to note that the main collective stakeholder and driver of any CN initiatives is the local community, be it organised and steered by a local government or not. This is particularly evident in the AlterMundi example that we will analyse in the next section, stressing that community initiative and engagement is not only essential to kick-start CNs but also – and mostly – to assure their enduring success.

2.3 The AlterMundi Network Model

When AlterMundi began working on the elaboration of a network model, the founders were operating in the context of a State plan called "Arraigo Digital"[22] which was designed in partnership with the National Ministry of Education in Argentina. The target of Arraigo Digital was high schools located in small towns (less than 3.000 citizens) and the objective was to teach Free Software and Community Networking to students and their communities. Only a pilot experience of this plan was carried out but the design goals survived the project together with AlterMundi's commitment to help small communities build their own communications infrastructure. The Arraigo Digital experience was therefore instrumental in the development of the technology as well as conceptual structure of the AlterMundi network.

The small town scenario imposed many particular challenges but also some advantages, compared to big cities. The main challenges were:

- the scarcity or absolute absence of networking experts;
- the low income of community members;
- the lack or very limited extension of network infrastructure.

On the other hand, the clear advantages of the rural areas were:

- the availability of usually quite clean WiFi spectrum;
- the easiness raising town-wide awareness on a specific project due to the small size of communities;
- the greater propensity towards joining forces to solve local issues.

This preliminary analysis led to some design goals about the features of the network model:

- the networks needed to be **easy to deploy** and maintain by unskilled people;
- the components needed to be **affordable** and locally accessible;

22 See http://codigosur.net/article/arraigo-digital-software-libre-y-redes-en-la-escue/

- it was essential to optimise such simple and affordable equipment, to achieve the best possible **performance**;
- the networks were to be designed to be **part of the Internet**, not just access networks.

Such fundamental features aimed at minimising costs and complexity to the end users while maximising network performance and availability. Notably, at that time of the network early conception (2011), there was much debate about the performance problems encountered by mesh networks based on off-the-shelf single-radio routers. Such networks suffer from the "half-bandwidth-per-hop"[23] problem, where each hop between nodes will decrease the bandwidth by half, due to the shared medium and half-duplex nature of WiFi radios. While some CNs avoided this problem completely by using a 100% infrastructure mode design with one dedicated router for each link, such networks are expensive and need a considerable manual configuration to get each node connected to its neighbours. This represented an important barrier with regard to ease of deployment and affordability.

The AlterMundi designers were looking for a network model where all nodes could be on an equal footing, so that every CN member would be able to fix problems in any node. Furthermore, due to mesh networks' higher resiliency and versatility (as in the possibility of circumventing potential obstacles), the AlterMundi founders decided to explore the establishment of a network model based on affordable multi-radio mesh nodes, with no single point of failure.

2.3.1 Early Attempts

The earliest attempt at an affordable multi-radio node was based on TP-Link MR3220 routers, which were, at the time, the cheapest routers – available in Argentina - with a USB port. This port was used to connect a second radio employing a USB wireless adapter. These nodes used two external "cantennas,"[24] produced at a local shop and completed by the people during network workshops. Interestingly, it was observed that the aforementioned router supports a wider range of power input (9V to 24V) than documented. Such feature, coupled with the easiness in modifying

23 See Strix Systems (2005).

24 The term cantenna is based on blending the words "can" and "antenna" and is used to define a homemade directional antenna, built with a metal can. Cantennas are frequently used in wireless CNs to increase the Wi-Fi signals' range. See How to Make a Cantenna http://www.wikihow.com/Make-a-Cantenna

the integrated Ethernet switch in this routers to support Power Over Ethernet, provided a very versatile unit in terms of deployment.[25] This node model, while very rudimentary, represented the first platform allowing to concretely start working on the software to make the "plug & play" deployment possible. Thanks to this hardware model, it was possible to deploy almost 20 nodes in José de la Quintana, which served as an important test-bed for both the hardware and the software involved.

2.3.1.1 The Initial Software Layer

AlterMesh

The initial firmware was based on the well-established OpenWRT[26] project and the main characteristics of the firmware were:

- free software;
- WiFi auto-configuration;
- random IP auto-assignment;
- layer 2 dynamic routing based on BATMAN-Advanced protocol;
- auto-discovery and sharing of Internet gateways;
- roaming inside the mesh;
- dual stack (private IPv4 /public IPv6);
- real-time node and link state mapping on a decentralized mapping service.

The Firmware Chef

The desire expressed by other networks to adopt this network model motivated the development of the Firmware Chef,[27] an easy-to-use web application to personalize a firmware, which is still active nowadays. This tool would let people to create their own customized firmware, based on a reference profile or on other networks' customisations. The server would then compile binaries based on the particular network configuration and, when flashed to the routers, would create a mesh tailored to the needs of the specific case. In line with the design goals regarding simplicity, the

25 See Altermundi. DIY PoE-enabled 100mbit router. http://blog.altermundi.net/article/diy-poe-enabled-100mbit-router/

26 See https://openwrt.org/

27 See http://chef.altermundi.net

most basic level of customization requires just providing a name for the network.

The Mesh Tunnel Broker

Another common limitation of the early network deployments was the lack of IPv6 adoption by commercial providers in the region. This posed a problem in regards to the goal of making the AlterMundi networks a part of the Internet, particularly the plan of making locally hosted contents and services publicly accessible from any end-point connected to the Internet.

For a brief period of time, several IPv6 tunnel brokers, such as Hurricane Electric or Sixxs, were used in order to get IPv6 connectivity. Over this period, it became evident that the latency over public IPv6 between two community networks in Argentina was inconvenient (in the order of 600ms). This was due to the fact that when using regular tunnel brokers, all IPv6 traffic from the network needs to go through the broker's gateway, thus imposing a double ~300ms roundtrip (Argentina-USA) for packets to reach from one network to the other. To minimise latency, it was decided to implement a new tunnel broker design, that would take advantage of the shortest paths available to the physical networks. This solution was implemented in 2012, it was called Librenet6 and it is still in service, providing IPv6 connectivity to communities in different continents. The Librenet6 design is simple: the tunnels are established using the Tinc software,[28] which creates an abstraction where every node in the tunnel can exchange traffic over layer 2 with every other node. The software finds the shortest paths between nodes across the underlying IPv4 network. The second component was a layer 3 dynamic routing protocol. Babel[29] was adopted for the configuration simplicity. Thanks to such configuration, each network advertises its IPv6 subnets and the protocol daemon at each border node configures the routing tables accordingly.

The result was a drastic reduction in latency, from ~600ms to ~30ms from a network in Córdoba to one in Buenos Aires, over a distance of 800Km. The IPv6 space for this service was provided by the Guifi.net Foundation, which decided to partner with AlterMundi, and the Internet gateway for the tunnel mesh network was located in Catalonia, home of Guifi.net.

AlterMap/LibreMap

At the time of the early deployment of AlterMundi, most CN maps were essentially maintained by individuals. Such maps aimed at showing

28 See https://en.wikipedia.org/wiki/Tinc_%28protocol%29

29 See https://en.wikipedia.org/wiki/Babel_%28protocol%29

the network structure, or at least the intended network structure, but they did not show the actual links and their state in real time. In order to improve this static situation and reduce the need for users' intervention, the AlterMundi community decided to implement a low footprint distributed service, based on Couchdb,[30] which would let each network host its own map-server, while allowing for data synchronisation with global maps, envisioning the possibility of getting a big picture of CN deployments worldwide. The AlterMap agent was installed in each AlterMesh node and a point-and-click web interface let the user pinpoint the node at the moment it was deployed. Further status-data was updated regularly by the nodes to one or more federated map-servers.

Importantly, this software was adopted by other CN projects and led to the creation of a successor, which was based on the same principles and born from collaboration with German developers of the Freifunk CN that were working on a similar tool. The partnership resulted in the creation of LibreMap.[31]

2.3.1.2 Limitations of the First Node Model

Over a longer period, several problems emerged with regards to the dual 2.4Ghz radio node and the firmware that had been developed for it. Some problems were easily overcome while others turned out to be true showstoppers, which led to the adoption of the next incarnation of the AlterMundi mesh nodes and software.

Hardware Layer

The first problem concerned bandwidth loss. Notably, although the nodes were dual radio, almost half the bandwidth was lost on each hop. Such loss was generated by interference between the two radios in the nodes, which persisted even at the most distant available 2.4Ghz WiFi channels (1 and 11). The lack of rf-shielding in the low-cost WiFi interfaces and the poor quality of the antennas made it impossible to completely solve this issue, although it was minimised by placing the radios and their antennas – using USB extension cables – at a vertical distance of at least 1m from each other. Furthermore, at the time it was impossible to find a USB wireless adapter that would be stable enough in ad-hoc mode, which was essential for the mesh structure. Atheros-based adapters were the most performant but in the end such units did not allow solving a variety of blocking issues and, therefore, it was decided to abandon their use.

30 See http://couchdb.apache.org/

31 See http://libremap.net/

Software Layer

It is important to note that the AlterMesh firmware was incredibly successful in its goal to make community networking viable for people with no previous networking knowledge. People from small towns would be able to build and deploy a 20-node network in less than two weeks after taking part in a two-day hands-on workshop, which included the actual construction of the network nodes and antennas. However, this model, based on a Layer 2 dynamic routing protocol (BATMAN-advanced), showed its limitations when towns started interconnecting.

From the perspective of a one-town network, the routing protocol would allow the correct discovery of optimal routes between nodes and to the Internet gateways. However, a further level of complexity emerged when a CN connected to another CN and the border node was not the same as the Internet gateway. Complexity further increased with the multiplication of such connections to the same neighbouring town and to others. This scenario could not be solved through the initial model, which was optimised for cases where the whole town would have only one exit node – to the Internet or to other neighbouring networks.

While a traditional community network deployment would have solved the problem by using an additional Layer 3 routing protocol (probably BGP) and increasing manual configuration and network aggregation at different levels, this strategy was not satisfactory for the AlterMundi community.

2.3.2 The current model

Dual-band Node

During the search for a satisfactory WiFi dongle, the AlterMundi developers came across the first dual-radio, dual-band off-the-shelf routers that became available in Argentina: the TP-Link WDR3500. While this router was approximately 50% more expensive than the previous router+dongle model, the advantages greatly outmatched the cost difference. Notably, this router provided a better CPU, more RAM and Flash memory, and it was 2x2 MIMO. The only problem it presented was the fact that the two radios would share the same set of antennas. Although such use was not problematic for very short connections (<300m), directional antennas were essential for every other scenario. This situation made the prospect of adopting the dual-radio router unsustainable due to the high cost of dual-band directional antennas. The AlterMundi architects decided to solve this problem with local creativity, which after some trial and error gave birth to the widely known dual-band semi-directional DIY antenna[32]. This design, based on a low cost locally made parabolic dish combined with some plastic water pipes, enabled 3 to 6 Km dual-band links with outstanding performance.

Another peculiarity in relationship to the dual-band MIMO 2x2 router[33] is that it is normally expected to employ both RF chains when communicating with any single neighbour, which in our case would have required having both semi-directional antennas pointing in the same direction. This would greatly reduce the feasible mesh paths originating from a single node. Instead, through experimentation it was deemed possible to point the two antennas in different directions, effectively disassociating the MIMO chains so some neighbours would be reachable over only one of the chains, and some over the other. To the surprise of many experts, this solution was not only cost-effective but also consistent in terms of performance, and even helped to identify some corner-case bugs in the wireless drivers.

Lastly, the use of BATMAN-advanced[34] for the dynamic routing proved to be a successful choice in this design, as this protocol always chooses a different exit interface for packets it receives, as long as the quality of the available links is similar. In practice, this means that a packet received by the 5Ghz radio is then transmitted through the 2.4Ghz radio to the next node. The fact that the radios share the antennas helps in this condition, as it yields links that are equivalent in both bands.

LibreMesh Firmware

A big challenge was outstanding: how to overcome the AlterMesh limitation in the scenario of effectively routing traffic amongst different Layer 2 mesh clouds (i.e. community networks). During the "Wireless Battle of the Mesh V6",[35] in 2013, together with core hackers of the CN movement, the AlterMundi architects were able to discuss and thoroughly understand the problem of large scale dynamic routing for a scenario of interconnected Layer 2 town-wide networks. This discussion undoubtedly stressed the importance of cooperation amongst various CN communities, convincing a number of teams that were developing similar firmware that it was time

32 See https://www.newamerica.org/oti/blog/do-it-yourself-antennas-for-community-networks/

33 See http://www.extronics.com/wireless/antennas/iant221_-_dual_band_2x2_mimo

34 See https://en.wikipedia.org/wiki/B.A.T.M.A.N.

35 See http://battlemesh.org/BattleMeshV6

to join forces. It was indeed at this very moment that LibreMesh was conceived, as a collaboration amongst eigenLab, qMp and AlterMesh projects.[36] Most importantly, since then LibreMesh has kept on being a collaborative effort involving an increasing number of CN communities from Italy, Catalonia, Argentina and Germany.

Dual-layer Routing

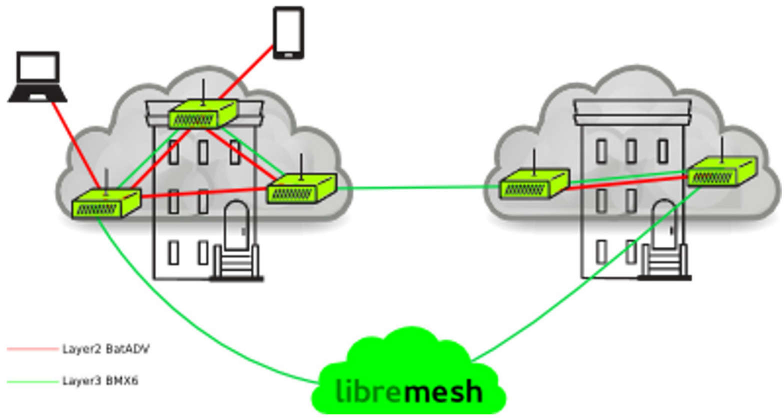
The solution to the core limitations of AlterMesh was to add a second dynamic routing protocol (bmx6)[37], which runs in parallel to BATMAN-advanced in every node of the network. All traffic inside the same Layer 2 cloud is routed through BATMAN-advanced, while routes towards other networks are handled by bmx6. This setup allows a unique combination of roaming capability (inside each Layer 2 cloud) with greater scalability (granted by the Layer 3 routing) while keeping network addressing simpler, avoiding unique IP address blocks configuration for each node.

Roaming

From the perspective of a client, every node in the network acts as a gateway to every reachable network (including the Internet). Transparent roaming is achieved by telling (via DHCP) the clients to use a special IP address as default gateway. Every node has this special IP, and corresponding MAC address, configured as their own, so when clients roam across different nodes while moving, they will have their packets routed by the immediate node they are currently connected to.

36 See http://libre-mesh.org/

37 See https://bmx6.net/news/14



Shared DHCP Leases and Global Name Resolution

The fact that every node is a gateway and hands out IP addresses through Dynamic Host Configuration Protocol[38] (DHCP) in a zero-configuration scheme creates the possibility of address collision. LibreMesh solves this by sharing DHCP leases amongst all nodes, so that each node knows what IP addresses have been assigned by every other node, to avoid collision.

This feature coupled with a system of DNS relay for each network based on Dnsmasq,[39] makes it possible to enable name resolution based on the client host name. For example, host.red.quintanalibre.org.ar will point to the IP address that was assigned to "host" by a node inside QuintanaLibre network. Any DNS server on the Internet is able to query this information directly, which is replied by the authoritative name server for the red.quintanalibre.org.ar domain, i.e. the internal name server in QuintanaLibre through its publicly accessible IP address.

In the case of networks that only have public IPv6 addresses (but not public IPv4), a dual-stack DNS relay is provided through AlterMundi servers. This host gets queries over IPv4 and relays them over IPv6 to the real authoritative name server inside the community network. This allows legacy IPv4-only DNS servers out on the Internet to query the IPv6-only CN name servers.

38 See https://en.wikipedia.org/wiki/Dynamic_Host_Configuration_Protocol

39 See https://en.wikipedia.org/wiki/Dnsmasq

2.3.3 Future challenges

While the current network model has demonstrated to be successful in relation to the goals that were established, it became evident in the AlterMundi community that the 2.4Ghz band is getting increasingly polluted even in small rural-towns. This creates a considerable problem for the current AlterMundi model as it breaks the interface alternating mechanism provided by BATMAN-advanced, which depends on both bands (2.4Ghz and 5Ghz) performing similarly. In addition to this circumstantial problem, the model itself has the limitation of using the 2.4Ghz radio both for mesh connections and for client access, which adds more congestion to the already burdened 2.4Ghz band.

Another important limitation, which concerns not only AlterMundi's network model but every CN that depends on replacing factory firmware with third-party alternatives, is determined by the FCC Regulation which obliges manufacturers to impede the possibility of changing radio frequencies through software manipulation[40]. Indeed, such regulation has driven many companies, including TP-Link, to close their hardware to third parties' firmware, effectively hindering CNs' ability to survive and grow.

The LibreRouter project

To overcome these problems, AlterMundi started an initiative aimed at developing an Open Hardware router that may offer an alternative option for CNs in every country that is not concerned by the FCC ruling. This router project, named LibreRouter,[41] won the 2016 edition of the FRIDA (Latin America) and the FIRE (Africa) grants and it is currently being developed by a team of experts from different countries. The proposed router specification includes three radios, two in the 5Ghz band for mesh connections and one in the 2.4Ghz band for client connectivity. It incorporates Power over Ethernet and outdoor casing, hardware watchdog, Gigabit Ethernet and an optional GPS module. It will be bundled with the LibreMesh firmware from factory to make the best use of these features.

40 See FCC (2014) as well as https://www.wired.com/2016/03/way-go-fcc-now-manufacturers-locking-routers

41 See https://blog.altermundi.net/article/el-proyecto-librerouter-premios-frida/

2.4 Conclusion: Fostering Sustainability through Connectivity

It is extremely important to stress that 60% of the world population is currently unconnected and 46% of the population lives in rural areas. (ITU 2015) It seems quite evident that traditional public and private strategies to foster Internet access have limits. Moreover, while commercial and state-driven models may have been effective to connect the first 40% of the population, the reality of the currently-unconnected communities is too dissimilar from that of the first "wave." Therefore, it seems important to explore alternative approaches that may lead to more fruitful outcomes and foster connectivity in a more sustainable fashion. CNs have proven to be a viable and sustainable alternative, with particular regard to those models aimed at empowering people through the use of simple and affordable technology. Not only do they show that connecting the unconnected can be done with a bottom-up approach but also that general assumptions as to what the Internet is or needs to be can be challenged. Indeed, the ultimate goal of CNs is not to propose yet another access plan or to transform the currently unconnected individuals into new consumers. On the contrary, the goal of CN is to create netizens who do not merely access the Internet from the last mile, but rather participate as co-creators of the Internet, developing content, applications and the infrastructure itself, from the first mile on.

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3. A Commons-oriented Framework for Community Networks

Leandro Navarro, Felix Freitag, Roger Baig, Ramon Roca

Abstract

This report introduces a framework for the analysis of Community Networks (CN), from a European perspective but applicable to other regions, with the aim of providing a sort of general taxonomy. The report first of all reviews and partially re-defines the concept of commons in the context of modern digital society, technologies, and infrastructures. Next a description of the general framework for the comparative analysis of different CN instances is given trying to set a "reference conceptual architecture" that can help understanding different organizational models and different implementations of Community Networks. The final part is devoted to a first comparison and classification of different models.

3.1. Introduction

The report is organised as follows:

a) An introduction to the concept of community networking infrastructures in the context of data networks;

b) A description of the general framework for the comparative analysis of different CN instances, mostly driven by Ostrom's commons principles;

c) A comparative analysis of different CNs, coupled with elements for a typology and discussion.

This report and the general framework is inspired by a detailed analysis of a selection of CNs, mainly guifi.net, FFDN, Ninux, Sarantaporo.gr, AWMN, Freifunk, B4RN, Rhizomatica, Altermundi, Zenzeleni.

This document is a shorter version of D1.2 "Report on Existing Community Networks and their Organization" "netCommons 2016" developed as part of the netCommons research project, which applies the framework to many of these CNs, provides a quick and raw list of CNs around the world, and a more detailed analysis of commonalities and differences.

3.2. Network infrastructures

According to "Wikipedia (2016b)" a computer network is defined as:

"a telecommunications network, which allows computers to exchange data. In computer networks, networked computing devices exchange data with each other using data links. The connections between nodes are established using either cable media or wireless media."

Computer networks, also referred as "data networks", provide an artificial medium for digital communication and access to information across distance and time that complements our natural limited capacities as evolved apes, to communicate in the acoustic space, see in a narrow frequency band of visible light, and access information in the physical space around us. Traditionally telecom services and access to the Internet were seen as an option, a luxury for corporations and the club of those citizens willing to pay premium to benefit from these artificial "superpowers".

The infrastructure that provide these commercial services was managed in most countries around the world by national telecom monopolies and later by telecom incumbents and other commercial (for-profit) operators. In recent times, the growing adoption of data networks as the best, and sometimes the only, option to communicate with many other people and access most information, has promoted that access to an essential (sometimes called "universal") service, involving governments legislating and regulating various aspects to guaranteeing to the public universal access to these privately provided services.

Furthermore, the evolution of services, both private and governmental, from commerce and entertainment to tax paying and education, has in recent years relied more and more on telecommunications services both as a means of reducing services costs and as a means to improve citizen service fruition reducing the time needed to obtain the service and allowing service fruition outside normal business hours.

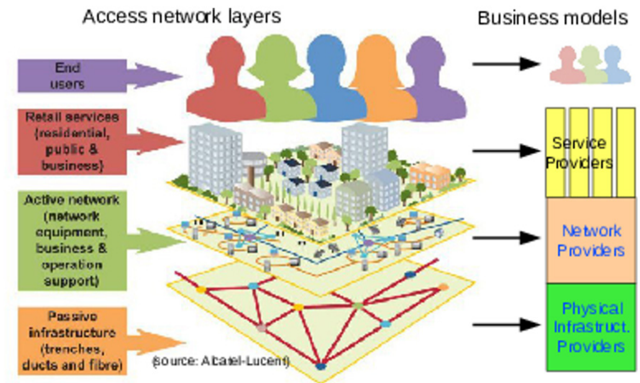

Figure 1: The components of a broadband network (with a focus on optical fiber) and the three service layers.

According to the broadband[42] investment guide of the European Commission "European Commission 2014" and supporting research "Forzati, Larsen & Mattsson 2010", the structure of a modern network service consists of three inter-dependent layers: a) the passive infrastructure, b) the active infrastructure, and c) the delivery of service, as illustrated in Figure 1. In the Open Systems Interconnection model (OSI model) "ISO 1994" the passive infrastructure corresponds to layer 1 (physical), the active infrastructure corresponds to layers 2 (data link) and 3 (network), and the delivery of services includes the remaining layers (from transport to application).

The most typical passive infrastructures are the traditional telephone copper wires, TV coaxial cables, optical fiber, wireless point-to-point or multi-point links and the corresponding dedicated (licensed) or shared (unlicensed open access) spectrum. The active infrastructure typically comprises a diversity of data-link protocols matching the associated passive infrastructure. It converges in most cases to an IP network on top and is sometimes also combined with network virtualization techniques.

These IP networks can offer a wide range of services such as interconnection to the global Internet, telephony as Voice Over Internet Protocol (VOIP), access to media content (such as television, radio, cinema), and

42 The term "broadband" is used to refer to fast data networks, in contrast to slow and narrowband dial-up telephone lines.

can be accessed by personal client devices or servers, typically through Ethernet cables or WiFi (the IEEE 802.11 family of standards) Access Points.

The deployment and operation of these networks and services requires investments that feature large economies of scale in urban areas with many citizens (customers). The concentration of customers in small areas and their grouping in buildings, make it a great business for commercial telecom providers. As the population density decreases and the distance to major cities increases or the economic capacity of customers decreases together with a lower level of socio-economic development, the margin for commercial exploitation decreases or becomes negative. However, there is growing consensus that it is important to provide these services to every citizen, in particular in remote or under-developed areas that are generally under-served when compared to more urban areas, and even public services are sometimes provided only remotely. As a result, public administrations have devised policies that promote and try to ensure a minimum level of service for all citizens independently of their location. These policies range from subsidies to network operators in exchange for offering services in these areas, to public investment in the development of complementary network infrastructures, or definition of public (regulated) prices for key services.

However, network infrastructures are in most cases under the control of former monopolies, now telecom incumbents. These entities control the offer and have strong lobbying mechanisms in place to influence regulation and discourage competitors. Except for the most developed urban areas, the typical situation is of lack of competition, defined as “market failure”. The typical market structure is rather disappointing, with a very small set of large telecom providers acting as oligopolies and exercising cartel practice, which justifies public intervention “European Commission 2014”. This has been recognized as a critical challenge by ITU in a report “International Telecommunication Union 2009” that explores and proposes options based on the principles of separation and sharing, typically managed by governments through legislation, regulation and subsidies. The most visible recommendations are:

- Extending access to fiber backbones: open access to bottleneck or essential facilities (like fiber infrastructures), that encourages the development of multiple providers of any size and scope, and promotes investment in a high-capacity infrastructure to unserved or underserved areas;

- Mobile network sharing: an equivalent to the previous but applied to the mobile network, applicable to both passive and active elements of the network;

- Spectrum sharing: promotion of the spectrum “commons”, with administrative, licensing, unlicensed bands, commercial or technical measures (like dynamic spectrum access or cognitive radio);
- International gateway liberalization: liberalization of international gateways, such as access to submarine cable systems, avoiding any anti-competitive control from incumbents;
- Functional separation: also known as operational separation, creating separate business divisions;
- Structural separation;
- Cost sharing and user sharing: sharing of a computer, mobile, Internet link, or content, across a group of people, such is schools, libraries, public-access tele-centres or shops.

Each of these measures can help develop new business models that can make a great difference in the expansion of the coverage and usage of data networks for the socio-economic benefit of every citizen in the world, and community networks can benefit from changes in these directions.

In Europe the European Commission has introduced the cost reduction directive with measures to reduce the deployment cost of high-speed electronic communication networks (2014/61/EU) “European Parliament and Council 2014”.

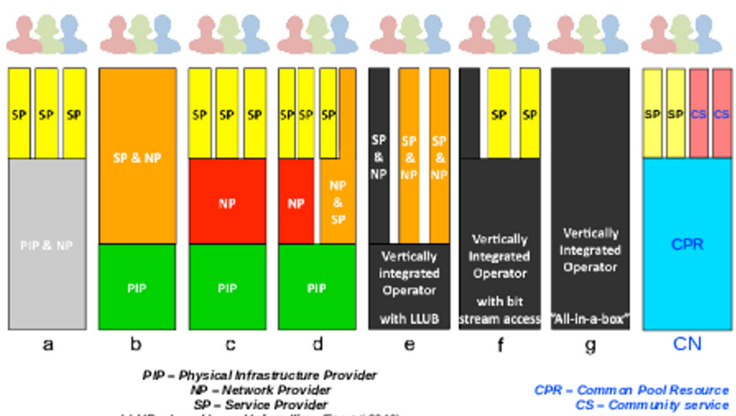

Figure 2: Different division and separation across the three service layers.

The typical business models of modern data networks typically follow one of the structural models depicted in Figure 2. Nevertheless, in some cases (and countries) functional or structural separation is in place to prevent anti-competitive, discriminatory behaviour by incumbents. The ultimate goal is to promote cooperative cost sharing schemes to reduce the cost of deploying infrastructures of any kind (telecom-related and others such as roads, water, electricity that require expensive civil works), and promote competitive offerings (market) to widen the choice and reduce the cost of services to customers.

In the rest of the report, we describe how community networks represent an alternative paradigm for developing network infrastructures and services. Such a paradigm can enable local communities to ensure their digital sovereignty, and take full advantage of the opportunities and benefits of cooperation and sharing towards their sustainable development. We will see how taking advantage of private and public initiatives and resources, communities can propose locally adapted self-organized cooperative schemes for realizing self-provided data networking solutions and sharing wireless links and spectrum, optical fiber, international gateways, and even spare Internet connectivity with other members of the community.

3.3 Community Networks

Crowdsourced computer networks are network infrastructures built by citizens and organisations who pool their resources and coordinate their efforts. The coverage of under-served areas and the fight against the digital divide are the most frequent driving factors for their deployment, although contributors often mention doing things for experimentation, fun or the act of contributing to the development of a new telecommunications model per se as alternative motives. The employed technologies vary significantly, ranging from very-low-cost, off-the-shelf wireless WiFi routers to expensive Optical Fiber equipment “Avonts, Braem & Blondia 2013”.

The models of participation, organisation, and funding vary broadly across these networks. For example, some networks are freely accessible, whereas others are run as a cooperative, and others are managed by federations of microISPs. A few examples follow[43]. Broadband for Rural North (B4RN) in Lancashire, UK, and Nepal Wireless Networking Project (NWNP) are networks built in response to the lack of coverage of the conventional operators. B4RN deploys and operates optical fiber in a cooperative way. NWNP “Thapa & Saebo 2011” is a social enterprise that provides Inter-

43 BARN: http://b4rn.org.uk/, NWNP: http://www.nepalwireless.net/, FFDN: http://www.ffdn.org/en, HSLnet: http://www.hslnet.nl/.

net access, electronic commerce, education, telemedicine, environmental. and agricultural services to a number of remote villages, using wireless technologies. French Data Network Federation (FFDN) is a federation of French Do-it-Yourself ISPs which comprises Digital Subscriber Line (DSL) resellers, Wireless Internet Service Providers (WISPs), collocation centres, and the like. HSLnet is one of the many cooperative fiber-optic networks in the Netherlands. All these networks are very diverse in many aspects, and only a careful structural analysis will allow to classify each under one or several models. This is the aim of this chapter.

In Open Access networks (OANs) "Battiti et al. 2015" anyone can connect to anyone in a technology-neutral framework that encourages innovative, low-cost delivery of services to users "International Telecommunications Union 2009". In other words: multiple providers sharing the same physical network. In many cases, these are publicly owned. Municipalities sponsor or build the physical infrastructure (fiber-optic lines, wireless access points, etc.) offering wholesale access, and independent Internet Service Providers (ISPs) operate in a competitive market using the same physical network providing retail services. The most well-known example is the open-access network in Stockholm by the public company Stokab "Felten 2010", having a key socio-economic impact in the region "Forzato & Mattsson 2013".

CNs are a subset of crowdsourced networks that is characterised by being *open*, *free*, and *neutral*. They are open because everyone has the right to know how they are built. They are free because the network access is driven by the non-discriminatory principle; thus they are universal. And they are neutral because:

a) Any available technical solution may be used to extend the network;

b) The network can be used to transmit data of any kind by any participant, for any purpose.

Representative examples[44] are Guifi.net in Spain, Fraifunk (FF) in Germany, the Athens Wireless Metropolitan Network (AWMN) in Attica region of Greece, FunkFeuer (0xFF) in Austria, and Ninux.org in Italy.

All of them include thousands of links, mostly wireless[45], but gradually integrating also optical fiber and optical wireless links.

44 guifi.net: http://guifi.net/, FF: http://freifunk.net/, AWMN: http://www.awmn.net/, 0xFF: http://www.funkfeuer.at/

45 The term *wireless* was broadly used to refer to this type of community networks, so that many of these networks are referred to in literature as Wireless Community Networks (WCNs), because originally WiFi technologies were the only one cheap enough and not subject to licensing to enable their use in non commer-

Although CNs have already been studied from several angles “Braem et al. 2013, Maccari 2013, Traverso 2014, Baldesi, Maccari & Cigno 2014”, there is still insufficient understanding of the practises and methodologies, which have given rise to such complex collaborative systems. There are many studies of guifi.net, the largest CN worldwide, from the structural “Cerda-Alabern 2012, Vega et al. 2012, Maccari & Lo Cigno 2015”, technological “Veja et al. 2015, Maccari et al. 2015, Baldesi, Maccari & Lo Cigno 2014” or organisational “Baig et al. 2015, Lo Cigno & Maccari 2014” points of view. However, there is lack of a common framework to analyse the non-technological aspects of CNs that were key for the initial development of each initiative. After more than a decade the landscape has changed significantly in several dimensions. There are nowadays more and diverse technology options available. Its usage and integration has been simplified. The costs have been reduced. In summary, technology has commoditised. Overcoming technological barriers brings in the challenges of organization, and related issues around participation, sustainability, resilience, adaptability, impact, This is the objective of the remaining of this Section.

3.4 Principles

The fundamental principles of most CNs, defined at the start to be fully inclusive, revolve around i) the openness of access to the infrastructure (usage), and ii) the openness of participation (construction, operation, governance) in the development of the infrastructure and its community.

Non-discriminatory and open access. The access is non-discriminatory because any pricing, when practised, is determined using a cooperative, not competitive, model. Typically this results in a cost-oriented model (vs. market-oriented) with the fair-trade principle for labour pricing. It is open because everybody has the right to join the infrastructure.

Open participation. Everybody has the right to join the community. According to roles and interests, four main groups could be identified: i) volunteers, interested in aspects such as neutrality, privacy, independence, creativity, innovation, DIY, or protection of consumers’ rights; ii) professionals, interested in aspects such as demand, service supply, and stability of operation; iii) customers, interested in network access and service consumption; and iv) public administrations, interested in managing specific attributions and obligations to regulate the participation of society, usage of public space, and even in satisfying their own telecommunication needs. Preserving a balance among these or other stakeholders is desirable, as

cial developments. Nevertheless, it is deliberately preferred to avoid the term, to decouple the concept of community networks from a particular technology choice.

every group has natural attributions that should not be delegated or undertaken by any other.

When these fundamental principles are applied to an infrastructure often result in networks that are *collective goods*, *socially produced*, and governed as *common-pool resources*.

Thus, a CN could be viewed as a *collective good* or a peer property in which participants contribute and share their efforts and goods (routers, links, and servers) to build a computer network. The peer property emerges under the operation of different Internet protocols, provided that the community rules such as community licenses, are respected by all participants.

The development of a CN is an instance of both *social* and peer production.The participants work cooperatively at local scale to deploy network islands, and at global scale to share knowledge and coordinate actions to ensure the interoperability of the infrastructure that is deployed at local scale.

The *common-pool resource* is the model chosen to hold and govern the network. The participants must accept the rules to join the network and must contribute the required infrastructure to do it, but they keep the ownership of hardware they have contributed and the right to withdraw.

The next section presents in more detail the theoretical framework of Common Pool Resources (CPR). More generally, it explains how various theories framing the commons and peer production concepts can be used to better understand and analyze CNs.

3.5 Network Infrastructures as Common Pool Resources

The theoretical framework of the commons in general and of commons-based peer production in particular, is a reference for the development, management, and scientific analysis of CNs.

As already discussed, the underlying principle behind CNs is the firm conviction that the CPR framework presents the optimal way to run a network, as a critical resource for the development and sustainability of a community. CPRs were studied in depth by E. Ostrom “Ostrom 1990”. In this section we map her findings to typical CN instances and introduce other notions, which can be applied to study CNs and inform their development, sustainability and organization. We also introduce work by other theoreticians of the commons, whose main contribution was to adapt Ostrom's framework, originally developed for environmental local CPRs, to a broader diversity of resources, including knowledge, cultural and digital infrastructure and internet/spectrum.

According to Ostrom, a CPR typically consists of a core resource that provides a limited quantity of extractable fringe units. In our case, the core resource is the network, which is nurtured by the network segments the participants deploy to reach the network or to improve it. The fringe unit is the connectivity participants obtain. Resilient CPRs require effective governance institutions to keep a long-term direction and deal with the struggle to handle many actors and changes in a complex system. The long-term direction is defined as *sustainability* in remaining productive or operational under the fundamental principles of the CPR, and the short-term goal is defined as *adaptability* in reacting and adapting to change.

According to Frischmann "Frischmann 2007", public goods and non-market goods, as network infrastructures, generate positive externalities (positive effects) that benefit society as a whole by creating opportunities and facilitating many other socio-economic activities. Therefore, open network infrastructures have great social and economic value, although their benefits are sometimes hard to measure. An infrastructure that is cooperatively managed and sustained leaves a greater margin of added value activities than commercial networking infrastructures developed competitively, making a great difference in developing regions or communities.

The commons can be fragmented into different subtypes. Ostrom developed her framework based on the analysis of case studies from local, mostly environmental commons and extended her study with cases from knowledge commons, cultural and digital commons "Hess & Ostrom 2011", composed by a resource, a community, legal rules, interaction (commoning), outcomes, evaluation.

Scholars further extended this work in an attempt to systematize knowledge commons with another collective volume "Frischmann, Madison & Strandburg 2014", infrastructure commons with the example of internet congestion and network neutrality "Frischmann 2012", and internet/spectrum commons "Benkler 2002".

These modified versions of Ostrom's framework look into the nature of the resource, of the community, the criteria of success, failure and vulnerability, and finally the political purpose such the importance of the commons for democracy and freedom.

Finally, the study of digital commons, with the major examples of free software and Wikipedia, gave rise to commons-based peer production "Benkler 2006". The study of CPBB develops a political economy dimension to the study of a type of commons, by shedding light on the purpose and the underlying political values carried by commons as a sustainable alternative to the production by the state or the market only. The construction of such a common infrastructure will require policy action "Benkler, 2003".

3.5.1 Artificial material commons

The "tree" of the commons has several branches: natural, knowledge and code, and artificial material commons that are key infrastructures for communities.

- The *natural commons*, studied by the classic Ostrom school, is brought by mother nature and the emphasis is in how these commons are self-managed sustainably for the benefit of a community and its preservation.

- The *immaterial commons* of knowledge and code that follows similar principles but requires a model for its collaborative production and its collective property, that Benkler "Benkler 2002" called "Commons-based peer-production". In this model, information and knowledge lie close to a non-rival resource, although the cost of finding it (requiring search engines) and accessing it (requiring content servers) consumes rival resources that can be congested (energy, digital devices as clients or servers). Moreover, knowledge and code do not constitute an exclusion barrier in developed societies, but generate exclusion in developing societies (cost of access and availability of access infrastructure such as servers, networks, client devices, energy, etc.)

- The *artificial material commons* are complex systems where peer production is applied to build some specific, traditionally material, resource resource pool (or system) that is critical for a community as an infrastructure or as a means for development. There is no clear cut between the natural commons and the artificial material commons, but a continuous transition whereby more and more value of the commons is related not to the natural resource managed, but to the complex engineering manipulation of it.

A traditional example of artificial material commons are the woods and lumber production and commerce in north-eastern Italy, traditionally managed by the *"Magnifiche comunità"* (magnificent community) "Degiampietro 1972, Ferruccio 1998, Comunità del Cadore 1953, Giarelli 2013". Here, on top of the natural resources, the communal benefit is earned and amplified through complex management systems, lumber transfer (from the mountains to the plains of northern Italy and the Venetian Republic in particular), and transformation: the resonance fir wood used in Cremona, Italy by Stradivari to craft his legendary violins was grown, cut, and seasoned by the 'Magnifica Comunità di Fiemme' in a management cycle lasting between one and two centuries and involving many different cultural and technical skills. The same woods and manufacturing are still today the source of the best resonance wood for string instruments and a source of high revenues for the Community.

Coming to modern times, a good example of artificial material commons are the pool of digital devices deliberately shared by a community that is willing to use, reuse, repair, refurbish and recycle "Franquesa, Navarro & Bustamante 2016" them for the sake of a sustainable circular economy.

3.5.2 Rivalry and openness

Another example are community networking infrastructures, the focus of this work. In the past, networking infrastructures were considered a club good (excludable and virtually non-rival as a commercial service) provided by for-profit ISPs to those fortunate to be in coverage areas and willing to pay the service fee. CNs are a social response to the wide recognition of connectivity as a basic human right, and therefore the network infrastructure connecting people becomes non-excludable. Modern network infrastructures are based on the packet-switching principle that provides a mode of data transmission in which a message is broken into a number of parts (packets), and transmitted via a medium that may be shared by multiple simultaneous communication sessions (multiplexing). That results in a multiple access scheme using switches and routers where packets are transferred or queued, resulting in variable latency, limited throughput, and subject to network congestion if traffic gets close to its capacity. Despite conceptually non-rival, its practical implementation in a community of people, information and network services requires careful capacity planning to cope with demand, provide good quality of service and avoid network congestion that degrades the effectiveness of the network.

Under these assumptions, real (production) network infrastructures should be considered rival (networks have limited capacity, and every possible packet in a network can only transfer a specific amount of data and its presence in the network delays other packets). Without a careful design and planning, a network infrastructure gets imbalanced, congested and therefore exhausted as a resource system that produces connectivity as consumable. This is the case at least for high-data volume applications, like video/audio content or latency-sensitive applications such as audio or video conferencing and gaming. At the micro-level, the cost of sending one extra byte or packet in an idle network may seem nearly zero (non-subtractable) and therefore not subject to rivalry. In typical networks, this cost is subject to traffic loads and how they compare to the network capacity (over-provisioning is desirable and common practice in all networks, but too much of it is not economically efficient due to cost): additional traffic has a cost and an impact in the rest of the traffic.

Networks typically perform some kind of traffic engineering to operate efficiently (and manage rivalry), and network owners have to monitor the characteristics and volume of traffic to plan capacity and invest in its capacity when congestion starts to degrade the quality of service perceived by its users. Many Internet links tend to saturate from time to time. As network paths involve several link hops, some degree of congestion is nearly always present. In fact, Van Jacobson in the late 1980's faced the problem of Internet congestion and together with the research community came with several mechanisms for congestion control "Jacobson 1988" in the most frequent transport protocol (TCP). Network users can generate large and virtually unlimited amounts of network traffic (e.g., each home user downloading content on a 1 Gbit/s optical fiber link) typically just limited by the speed and the cost of their link (and not by the cost of its data traffic). Internet peering disputes between "eyeball" ISPs, transit ISPs, or content ISPs, are not an exception "Bafna, Pandey & Verma 2014", and typically capacity upgrades in network links result in elastic increases of traffic expanding and adapting very quickly to the new capacity of the link.

Therefore we can consider that production network infrastructures are typically subject to congestion, and therefore connectivity has to be considered rival. While commercial ISPs try to maximize benefit and minimize company risk in a competitive market (therefore an excludable resource sold at the highest possible market price), the goal of CNs is to maximize social inclusion, in terms of number of participants, coverage and cost, using a cooperative model where risks, costs and management is shared among the participants. This results in a network infrastructure that produces connectivity as close as possible to the ideal of non-exclusion, and under a peer property, peer production and peer consumption.

In fact, the recent verdict of the U.S. federal court classifying the Internet as a common carrier (type II), or the spirit of the European Regulation on a Single Telecom Market mandating network neutrality, imply an organisation or service that transports goods or people for any person or company and that is responsible for any possible loss of the goods during transport, under license or authority provided by a regulatory body "Wikipedia 2016a". A common carrier is distinguished from a contract carrier that transports goods for only a certain number of clients and maybe not anyone else. A common carrier holds itself out to provide service to the general public without discrimination. Community Networks are not common carriers offering a service to anyone external to the network infrastructure, but open for anyone to join to access to contribute infrastructural resources and consume connectivity, and participate in the management and governance of the commons. As with common carriers, there is a commitment to no discrimination and, hence, neutrality at all levels (access, participation, contribution, consumption). In summary, whereas a common carrier provides open access to the service, without exclusion other than the rules of access that may require to pay the service fee, in commons (and common property/self-management) members of a certain group can exclude non-members.

In that respect, infrastructure commons also favour the *political autonomy* of their participants, that is the ability for an individual to make choices and determine the course of her life free of external manipulative forces. As Yochai Benkler explains, autonomy is adversely affected by concentration and increased top-down control over communications resources "Benkler, 2006".

3.6 Stakeholders

In general, an instance of commons is composed by a resource (the CPR), which is governed, according to rules adhering to the commons frameworks, by a community. This community may be composed by several types of actors. This section presents these actors, and more broadly the whole space of stakeholders, in a CN based on their roles, status, rights, and obligations.

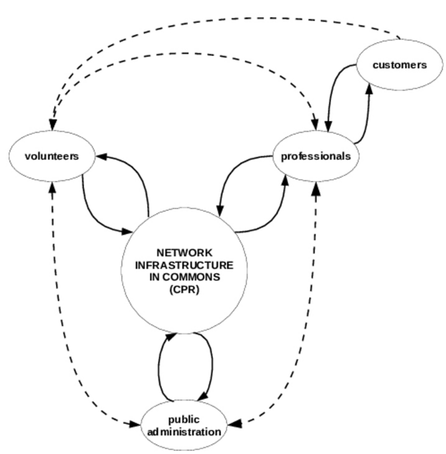

Figure 3: Stakeholders (as defined in the guifi.net network).

It is essential to clearly identify the interests and specific tasks of the different stakeholders, and the relevant conflicts of interest. As depicted in Figure 3, there are typically four main stakeholders. The *volunteers*, the initiators of the project, due to their lack of conflicting economic interests for each individual, are responsible for the operation of the tools and mechanisms of governance and oversight. The *professionals* contribute quality of service, and their *customers* bring the resources, which make the ecosystem economically sustainable. The *public administrations* are responsible for regulating the interactions between the network deployment and operation, and the public goods, such as the occupation of public domain. All participants that extract connectivity must contribute infrastructure, directly or indirectly, and can participate in the knowledge creation process.

As the community managing a commons can be decomposed into various sub-communities depending on their role, the bundle of rights “Schlager & Ostrom 2015” will become a useful additional analytical grid to further decompose these tasks. The bundle of rights includes rules on the right of:

- Access: to enter and connect,
- Withdrawal: to extract resources from the system (obtain connectivity from a network),
- Management: to regulate usage, make improvements,
- Exclusion: to determine who will have access and how this right can be transferred, and
- Alienation: the right to sell a portion of the resource (e.g. by professional participants selling connectivity to their customers).

Different stakeholders relate to property rights, that as Schlager presents “Schlager & Ostrom 2015” for natural resources, results in different access rights, with authorized users (customers) that are given access (connecting) and withdrawal rights (consumption or harvesting connectivity) through services provided by professionals or volunteers to have equivalent rights to manage or govern the infrastructure.

The rules related to joining a CNs (access), imply adding a network node and accepting the formal or informal rules of the community (sometimes the community license or any kind of agreement). The mechanism (inclusion and exclusion) is defined by a deliberation process among the assembly of participants (having the right for management) and generally implemented and automated by a software service to register, enroll and configure the new resource unit (link and router). Once the connection is successful the user is immediately able to consume connectivity but also provide connectivity to others connected to his router. Therefore users are both consumers and producers of connectivity, and joining implies also extending the resource system in the new location and allowing third parties to extend it beyond. Access and connectivity usage is not limited to the registered user, but usually his right is informally shared with anyone connected to his local (e.g. household) network (authorized users).

In a few cases, people may join a CN using an end-user client device (terminal or host such a laptop, desktop, server, or mobile device but not a router, using a WiFi Access Point or Ethernet cable). In this case, these participants are pure consumers of connectivity (or some specific application service) that do not extend the resource system. While not all CNs include this case, that form of participation allows externals or visitors (anonymous or not) to take advantage of the connectivity provided by the infrastructure, like if it were an open-access resource for the benefit of the local community at large. Sometimes this type of access is provided in collaboration with an institutional partner like a government along indefinite periods (e.g. community access in an area for those registered in the public library, educational or telecentre) or definite periods (e.g. an event, an emergency). In some cases these clients are registered users that can consume connectivity in a place with a client device in one place while contributing connectivity and expanding the infrastructure in another part of the network.

Compared to natural commons, CN make less or no distinctions among participants: all members are co-owners (of his network router and link), proprietors (enabled to participate in management and inclusion/exclusion), claimants (management). Only informal users of local/home networks and customers of member ISPs can be considered plain authorized users (consumers but not citizens in political terms). This level of potential participation is supported by computer-based coordination tools, although the effective decisions and actions are effectively performed by a small minority of motivated and trained participants.

We even find squatters: participants that do not follow the community rules and hide from the rest of the community, but use the network infrastructure (no contribution, at risk). Frischmann in "Frischmann et al. 2013", studying efforts to extend Ostrom's work on environmental commons to knowledge/cultural commons, showed how the classical free-rider of the tragedy of the commons can be applied and which lessons can be learned.

Withdrawal is related to obtaining connectivity from the community infrastructure. It is difficult to think about a community or regional network infrastructure that is isolated, connecting, for instance, different community members, local schools and organisations purely among themselves. Given the value of expanded connectivity, informally expressed by the

Metcalfe law “Shapiro & Varian 2013”, connectivity to the Internet represents a key added value. Different CNs have different approaches to adding Internet connectivity and managing it in a sustainable way. While in some cases this connectivity is intrinsically part of the infrastructure commons, in other cases is left outside the infrastructure commons, as an additional service. Sometimes it is considered equivalent to “content”, an added value ingredient that is simply transferred inside packets of connectivity and that goes through an Internet gateway, and therefore considered a separate concern and left outside the network commons. Some other communities provide default basic Internet connectivity to any node in the CN (e.g. with a common Internet interconnection gateway subsidized by third parties such as server hosting in a community data centre). Another approach is that Internet connectivity is contributed by volunteers, connected to both the CN and their own (personal) Internet access, that share for free (or a fee like in the FON commercial service) some of their spare connectivity with other community members. Another way is that Internet connectivity is managed and provided by a cooperative or crowdfunding model by a group of participants that share a common connection to the Internet in one network location and use tunnels over a CN to divide and access their share of connectivity remotely (e.g. eXO association in guifi.net).

Several CNs also act as an Internet eXchange Point (IXP) that is connected to other external ISPs and networks, and therefore is able to allow paid or peering transit traffic. In these cases, the CNs facilitate the cooperative aggregation of Internet capacity among several participants in the CN, which reduces the cost for each (cost sharing: paying only for their portion of traffic instead a full link) and the reliability of the Internet access (economies of scale: potentially benefiting from more redundant links than what a single participant could individually afford).

Each community has its own implicit or explicit agreements for the contribution (of resources) and withdrawal rights (operational level), and collective-choice level (*management*, *exclusion* and *alienation* in natural resources). Network infrastructures, as artificial material commons, may also require investments in infrastructure (maintenance, repair or expansion) and economic compensations among participants to correct imbalances and promote investment (reduced risk or incentives). Different compensation or investment mechanisms are considered such as crowdfunding, contracts, accounting systems, local currencies. Conflict resolution, like in many other commons, is a critical component to the stability and sustainability of the network infrastructure. Typically some reputable or experienced participants are selected for the role of mediation and arbitration.

The constitutional choices in each CN vary, according to the local characteristics and initial decisions. In some cases, a community license has been developed or adopted and agreed. The license should be explicitly or implicitly endorsed by all participants, and prescribe rules that determine rights or freedoms around *joining* the network and extending this right to anyone (as part of a resource system), *using* the network (provided no harm is intended or done, including traffic neutrality), providing services and content to others (for profit or not), and transparency (understanding, sharing knowledge) to promote participation in its management and governance. The transitivity of all rules result from the pooling nature of a network.

3.7 Implementation of the governance

This section discusses how the governance architecture in Section 6 can be implemented as governance tools in diverse CNs.

3.7.1 Communication tools

A network infrastructure commons has an important challenge in communications as usually participants are not only widespread, but also they tend to depend on the network infrastructure to communicate and coordinate: the community manages its commons network infrastructure by using that commons with components contributed by themselves. This creates and extra level of commitment[46] but also makes the task more complex by the need to rely mostly on digital communication. Due to the widespread of locations and the technical nature of its participants, collaborative tools of all kinds tend to flourish in CNs. The following are the most common:

Website It is the main participation and coordination tool. It integrates all the software tools described above, providing a complete platform for designing, deploying, and operating CNs.

Mailing lists These tend to be the preferred communication method for discussion. Mailing lists may have global, geographic, or thematic scope, and are most open for participation.

Social Media Local or global platforms for social interaction and information sharing are used to handle documentation and discussions. Work-

46 Typical terms are “Skin in the game” for involvement, “Eating your own dog food” for using your own tools, and the “sink or swim together” for the interdependency.

ing groups are public by default, but closed ones also exist to protect sensitive information.

Face-to-face meetings Face-to-face meetings play a very specific role in strengthening social relationships. Local meetings can be quite frequent (usually periodic: weekly, monthly, etc). In these meetings the participants work on their projects and help newcomers to join the group and the network.

3.7.2 Participation framework

The legal framework for participation in the network may include:

License The formal or informal CN license of neutral participation and traffic management. Examples of that are the Network Commons License (NCL) or FONNC in guifi.net, the Wireless Commons Manifesto in Ninux.org, or the Picopeering agreement (PPA)[47]. The licence sets the fundamental principles and the articles precisely establish the participant's rights and duties. Ideally, it is written to be enforceable under the applicable legislation to mitigate uncertainty, and should be developed through a participatory deliberation process.

Legal entity that gives a legal identity to the initiative. Its foundational mission is to protect, promote, coordinate and arbitrate the network commons. Its authority is frequently based on the reputation of the people involved, more than the legal strength of the entity.

Collaboration agreements with third parties such as professionals, public administrations, third-party organisations.

3.7.3 Network management and provisioning software tools

CNs need community network management platforms "Kos, Milutinovic & Cehovin 2016" to manage the different components that make up the network infrastructure, configure devices and network elements, reduce errors, facilitate the maintenance and operation of the network and lower the entry barrier for participation. These tools are typically integrated in the public or internal web site of the CN. Typical components may include:

47 FONNC: http://guifi.net/en/FONNC, PicoPeering: http://www.picopeer.net/PPA-en.shtml

Mapping tool that combines geographic maps with network maps to collect and share all the knowledge about the network and the participants involved in it;

IP addressing and routing tool to coordinate the IPs assignment and routing configuration;

Device configuration tool to automate the configuration of network devices;

Network monitoring tool to assess the status of the network, visualise usage, and identify problems or bottlenecks;

Network crowdfunding tool to coordinate the collection of voluntary contributions of money to fund new or upgrade existing nodes or links that could benefit several users directly or indirectly.

3.7.4 Governance tools

These are the socio-economic tools that CNs can develop to keep the infrastructure and the project/community itself operational. It is common to find tools for a) *Conflict resolution*, which may include a palette of graduated sanctions to resolve flame wars between participants that may threaten a given CN, and b) *Economic compensation*, to compensate for imbalances between investment in the commons infrastructure and network usage.

3.7.5 Sustainability

Analysing the design of long-enduring CPR institutions, Ostrom "Ostrom 1990" identified eight principles, which are prerequisites for a sustainable CPR. We now discuss their application to these human-made resource systems that provide connectivity:

1. **Clearly defined boundaries**. The fundamental principles of open and non-discriminatory access, and open participation in the life of the network are accommodated into instruments such as the community license, the management tools, the specific collaboration agreements with professionals and third parties, which prevent exclusion and regulate open and fair usage of the resource.
2. **Rules regarding the appropriation and provision of common resources that are adapted to local conditions**. The congruence between appropriation (usage of the network) and provision (expansion of the network) is usually mediated by common network management and provisioning tools that assist in assessing the sta-

tus of the network and its usage; also by tools that assist in the expansion of the infrastructure covering the mapping of the nodes, their configuration, and even the crowd-funding or cost sharing of new or upgraded network nodes and links.

3. **Collective-choice arrangements that allow most resource appropriators to participate in the decision-making process**. Complexity and transaction costs grow as the network grows in size (number of nodes, links, distance, participants). This complexity is managed by social structures with diverse representation from all CPR stakeholders, and such open structures as the local and global face-to-face meetings, and the digital participation tools such as social media and mailing lists. In all these structures, the community of those who use or participate in the construction of the resource can participate openly.

4. **Effective monitoring by monitors who are part of, or accountable to, the appropriators**. Monitoring is performed with the assistance of network management and provisioning software tools that provide a common information base about the history and status of the common infrastructure resource; and the lead of many local trusted senior members that rely on that open data and coordinate decisions when needed. These decisions are accountable, deliberated, reported in the communication tools, and recorded in the organisational history.

5. **Graduated sanctions for appropriators who do not respect community rules**. Each CN has its own conflict resolution system with methods to deal with users who negatively affect the common infrastructure resource.

6. **Conflict-resolution mechanisms which are cheap and easy to access**. Each CN has its own way to address these conflicts in a cheap, easily accessible, efficient, effective, and scalable manner, which enables it to address a wide range of conflicts around the network.

7. **Self-determination of the community recognised by higher-level authorities**. Each CN has its own way to validate and enforce its rules and structures according to the different levels of legislation.

8. **In the case of larger CPRs, organisation in the form of multiple layers of nested enterprises, with small local CPRs at their bases**. Larger CNs have second-layer organisations, providing a federated CPR with many aspects in common, and interacting with external organisations in the local and global scope in many aspects.

3.7.6 Adaptability - Adaptable Governance

The concepts and governance tools of CNs relate to what Ostrom "Ostrom 2008" outlined as five basic requirements for achieving adaptive governance:

1. **Achieving accurate and relevant information, by focusing on the creation and use of timely scientific knowledge on the part of both the managers and the users of the resource**. Communities produce open knowledge about practices and experience, and work with the scientific community to co-develop and apply scientific knowledge for the best development, management, and usage of the CPR. Collaboration agreements with academic and research organisations such as this project is a proof of accomplishment of that criteria.

2. **Dealing with conflict, acknowledging the fact that conflicts will occur, and having systems in place to discover and resolve them as quickly as possible**. The facts about the CPR are collected and managed by the different network management and provision tools. The rules in each community license and collaboration agreements define the limits that determine conflicting situations, quantified and discovered by inspection of the facts collected by the previous tools.

3. **Enhancing rule compliance, by creating responsibility for the users of a resource to monitor usage**. The openness principle requires users to publish open data about the network and allow the monitoring of nodes and their traffic. This requirement is supported and facilitated by the network management tools.

4. **Providing infrastructure, that is flexible over time, both to aid internal operations and create links to other regimes**. Each CN has its own structure to understand and adapt to changes over time, oversee the evolution of the CPR, facilitate the internal operation, and maintain links with external organisations and other regimes that coexist, interact, and interoperate with the CPR.

5. **Encouraging adaptation and change, to address errors and cope with new developments**. Each CN has its own structure to play an overseeing and steering role (sometimes referred to as a second level or umbrella organisation). This role should be driving feedback, organisational learning, and forecasting.

3.8 Services provided

CNs provide *network connectivity*, local or regional IP networks that enable inexpensive interaction and access to local digital content and services. Local web content, files, video content of local interest can be accessed through the CN infrastructure. Local services that allow local communication are also offered, like VOIP services, web cams, environmental sensors, live video streaming, search engines, remote file repositories, backup storage, among many other community services.

In addition, once part of a local network infrastructure, there is the issue of interconnection and access to the global Internet. That can be reached through an Internet Service Providers (ISP) available inside a CN. These ISPs can be wholesale (transit for organisations) or retail (for individuals) commercial or non-profit providers (e.g. the community or a specific group or cooperative), citizens sharing their unused Internet access capacity with neighbours and friends, public or private organisations offering a limited Internet access as a complimentary service.

Furthermore, there are public and private agents concerned with facilitating Internet access for other local citizens or visitors, at least to content of local interest. It is quite common to find free and open Internet access, offered through WiFi access points in public locations. When connected to a CN, these WiFi accesses provide an entry point to the CN and its world of content and services, and through local ISPs to the open Internet. That kind of Internet access with limited functionality is widely recognized as not constituting unfair competition with commercial telecom providers[48].

Internet access through web proxies is clearly a limited form of access compared to an IP tunnel as the service is usually restricted to a set of protocols/ports, while it can enhance privacy as origin IP addresses are hidden. For these reasons, many non-commercial providers in CN provide that kind of Internet access service, available to local visitors through WiFi Access Points and remotely to other CN members, at no additional cost. This is an inclusive and cost effective model to provide limited Internet (typically Web) access, complementary to commercial offerings.

48 Checked against the National Markets and Competition Commission (Spain). Similar schemes can be found in many other national legislations.

3.9 Implementation of the infrastructure and impact

Customary measures such as geographic spread, number of nodes and locations, number of actual and reachable participants, km of links help to quantify the implementation of a CN in a given community: the coverage and service is providing there.

However, assessing the local impact of CNs is difficult as it relates to the social value created by allowing additional users to access and use a network infrastructure "Frischmann 2007". Doing so permits or enhances the production of a wide range of downstream producers of private, public, and non–market goods.

It is clear that self-organized and self-provisioned network infrastructures contribute to truly universal service, dramatically lowering the barrier of access. This is realized through access to inexpensive commoditized hardware and software, spectrum and knowledge, much in a similar way as Free and Open Source Software and Technology has contributed to provide inexpensive options for access to software, contributing to sustainable development "Sowe, Parayil & Sunami 2012".

Another, more tangible, indicator of impact has to do with network access and usage characteristics by the local community. This is related to the accessibility of the network infrastructure by local citizens and the added value it provides to them. Customary indicators can be the volume of locally produced and served content, local services or applications, number of registered users, number of access points for client devices in public places, involvement of civil society organisations, number and type of open community events, training activities, participation and network support to community events, etc.

Social inclusion is a key opportunity for CNs as inclusive and participatory organisations. Complementary to creating opportunities for including everyone in the digital society, these commons infrastructures create opportunities to involve, support not only the unconnected but also balance, include and promote participation of minorities. That is the case for the gender imbalance, and the inclusion of vulnerable groups ("the excluded" or "less included") like migrants, linguistic minorities, Lesbian, gay, bisexual and transgender (LGBT) people, unemployed or with fragile employment, students, handicapped, ill-health, with non-stable homes, less educated.

CNs are complex and sophisticated objects mixing local deployment (as for natural commons) with global connectivity (as for digital commons), physical infrastructure with knowledge, and interacting with urban commons. Thus, our hypothesis is that a plurality of approaches will better inform our analysis beyond Ostrom's CPR.

3.10 A comparative analysis and discussion

Community Networks have a) macroscopic and external aspects, as an infrastructural resource system critical for a given community, that can be measured in terms of coverage and socio-economic impact; b) macroscopic and internal aspects that reflect coordination and adaptation according to its institutional structure, constitutional principles; c) microscopic aspects that reflect individual changes and interactions that reflect the specifics of the self-organized and de-centralised structure of these institutions, that differ across places.

We have explored the mappings between these institutions created by communities of practitioners and the world of theories about commons, both from a theory perspective, from the practice and social action and vice-versa. Network infrastructure commons, by its mission of digital inclusion and the rivalry of packet switched networks, not rival in theory or small scale but quite rival when implemented and deployed at scale in communities, are always at the brink of congestion. We are fortunate that the Internet technology is sensitive and reactive to short term congestion (queueing of IP packets in devices, congestion-avoidance in TCP). Furthermore, CNs have developed institutional tools to handle sustainability and resilience of these infrastructures. This is achieved by balancing contribution and consumption and promoting and supporting maintenance and expansion. The result is more participants with more connectivity resources and wider reach.

There is a distinction between the data links (wired or wireless), the network infrastructure (the resource system formed by routers and links), the content available and the services that operate over that infrastructure, and the interconnection to the global Internet. Each of these ingredients can be bundled or treated separately. For instance data links can be either built from commodity devices or obtained from third parties such as dark fibre operators or open access network operators. The rest can come from hosts inside the CN or from outside through interconnection infrastructures like Internet eXchanges.

Participation in the infrastructure results from the dilemma of open access versus a commons model. This results in technical choices and a balance between an open access network with access points that allow connecting terminal devices (a computer) that act as consumers of connectivity, and a prosumer model with intermediary devices (a router) that expand the coverage and capacity of the network. The technical choices in the computer network relate to organisational choices in the access and sustainability of the commons infrastructure.

Differences in access methods and level of involvement lead to different types of stakeholders: authorized users with terminals (and access point users), full participants with their own routers, and professional participants that may deploy, manage, and maintain from a few to many nodes in the infrastructure. The operational procedures, the governance mechanisms and collective-choice actions can and should take these roles into account. There are other relevant stakeholders such as governmental orgs, commercial participants, the role of IXPs, content and service providers. The coexistence and complementarity of all these is critical for the subsistence and expansion of these infrastructures. The neutrality/genericity of a network infrastructure allows not only community participants but also external participants outside the scope of the CN to benefit from it.

As technology savvy social groups, the promoters and participants have developed or adopted a wide range of tools to support coordination, management, governance, transparency and monitoring of the resource system. This computer-supported coordination and sharing tools has enabled CNs reaching much higher scale and formalisation of procedures. Along similar principles, each CN under analysis has develop comparable but sometimes surprisingly different ways to achieve similar goals.

The cooperative model of these infrastructures oriented to cost sharing, without extracting value (profit) from the infrastructure itself (although possible with the usage and alienation of connectivity), contributes to create socio-economic benefits, as in many other critical infrastructures for society. Measuring the impact is the key test to the relevance and impact of this infrastructure. That is difficult to assess as it escapes the pure economic impact and has multiple effects on most activities that can benefit from the availability of an inclusive and welcoming communication infrastructure.

These constructed commons infrastructures result in formal and informal rights implemented as standardized documents such as license, agreements, settlements, etc. as a result of constitutional choices, that range from non-existent, informal, formal in different CN, and that are defined or prescribed in an early constitutional phase or later on in the lifetime of CNs with more or less conflict in their adoption.

Legal recognition is an important factor given the infrastructural nature of the commons. The legal implications of the resource system (a telecommunications or networking infrastructure), the kind of extracted resource (connectivity and the regulation of service provision), the competition and coexistence with external actors (other ISPs and telecom providers) and the interaction with the public administration that regulates many aspects such as regulation of access to public space (radio spectrum, node and link deployment, sharing with other utilities).

The complexity and challenges around this environment suggests the development of second layer organisations and federated structures that can bring efficiencies, economies of scale, coordination and stability to these initiatives (e.g. in terms of legal methods, software development, knowledge sharing, legal protection, research, influence in policies and regulation). Several international initiatives and forums have allowed and supported communication and coordination among CNs, where this research is contributing.

Research is being recognized as key for the refinement and resilience of CN, leading to understanding, optimization, but also to the development of solutions to blocking factors in these infrastructures in the short or medium term.

A key challenge is the effect of scale (in number of participants, in network speed, in geographic coverage) that can have in the diversity of ways to organise according to local particularities, and the need for standardisation and avoiding the “single-point-of-failure” of a few leaders and teams that are putting a lot of personal time leading these initiatives. In this case sustainability and scalability could come with professionalization, but that may have also transformational effects on the structure of these initiatives.

Several of the key factors are represented in Table 1 that allow a comparison of the different features of the CNs that we have closely worked with.

Community	Scale	Commons-based governance	Legal representation	Infrastructure	Economic model	Licensing model
Guifi	21 provinces in Spain, and for instance 41 counties in Catalonia, other countries: Africa 4, America 16, Asia 2, Europe 14	Mixed (decentralized at local level but strong commons-based gov. at level of Guifi.net foundation). Related groups around software, Internet connectivity, contents as commons	Yes (local and national: telecom regulation, agreements with external orgs, tax, clearance of compensations, research, development)	Decentralized optical fibre and WiFi networks, acts as regional IX (private transit providers, mechanism to share and access transit capacity)	Subscriptions, crowd-funding, economic compensation system (importance of professionals)	Community License (FONN), agreements with external orgs, and compensation agreements
FFDN	28 local organizations/1500 subscribers	Decentralized (importance of core volunteers)	Yes (both local and national) + litigation	Decentralized (WiFi) / Centralized (leased ADSL)	Membership fees, subscriptions, donations	Bylaws, internal rules (réglement intérieur), charter of good practices and common commitments
Freifunk	304 local groups	Very decentralized	No (but litigation strategy nevertheless)	Very decentralized (free contribution of WiFi access points)	Volunteer contribution by citizens and professionals	Informal agreement
Ninux	350 nodes	Decentralized (importance of core volunteers)	No recognised legal entity	Decentralized in theory (WiFi), but bottleneck at super-node level	Volunteer contributions	Pico-peering agreement
Sarantaporo	153 nodes	Organization-centered (local support groups, open meetings, participatory design)	Yes (Non-Profit Organization)	Decentralized (WiFi) / Centralized bandwidth provider	Volunteer contributions, individual donations, collective donations, subscriptions, collaboration with companies	Informal agreement

Table 1: Comparative table of main European CNs

Beyond that, we have collected a few facts of interest from several CNs around the world, elaborated in 2015 from mainly email interaction with members of the different community networks and collected through forms. We include in this report in the form of tables, as a resource since it provides a more global perspective in terms of general and organizational aspects.

Name	Location	Active (years)	#Nodes	#Users	#Active partcp	Env.	Socio-econ Env
Kansas City Freedom Network [1]	kansas city, MO, USA	3.5	100	600	15	Urban	Developed
DeltaLibre [2]	Delta de Tigre, Argentina	4.5	70	200	20	Rural	Developing
QuintanaLibre [3]	José de la Quintana, Córdoba, Argentina	5	53	250	10	semi-rural	Developing
Berliner Freifunk Community [4]	Berlin, Germany	14	400	30000	100	Urban	stable
Seattle Community Network [5]	Seattle, WA, USA	22	1	500	20	Urban	Developed
Athens Wireless Metropolitan Network [6]	Athens Greece	14	3000	5000	800	Urban	Developed
Wireless België [7]	Belgium	12	700	5000	25	Urban	Developed
Chiang-Rai MeshTV [8]	Huay Khom village, Mae Yao subdistrict, Muang district, Chiang Rai, Thailand.	2.5	40	120	40	Rural	Developing
TakNET [9]	Thai Samakhi village, Mae Sot district, Tak, Thailand	3.5	20	60	30	Rural	Developing
Zenzeleni Networks (Mankosi Community Wireless Network) [10]	Mankosi AA, Nyandeni Local Municipality, Eastern Cape Province, South Africa	3	13	1000	10	Rural	Developing
Ninux-Firenze [11]	Firenze, italy	4	25	15	10	Urban	Developed

Name	Location	Active (years)	#Nodes	#Users	#Active partcp	Env.	Socio-econ Env
guifi.net [12]	Agnostic (mostly Catalunya, València)	13	32000	60000	200	all	
Sarantaporo.gr WiFi Community Networks [13]	Sarantaporo and surounded villages - Central of Greece	6	153	5000	65	Rural	Developing agricultural economy
Wireless Leiden [14]	West of The Netherlands	14	120	4000	30	both urban and rural	Developed
Cybermoor [15]	UK, Cumbria	14	15	300	500	Rural	Developed
wlan slovenija - open wireless network of Slovenia [16]	Slovenia	8	400	-	-	mixed	Developed
ninux.org Roma [17]	Rome, Italy	13	172	-	35	Mainly urban	Developed
Bogota Mesh [18]	Bogota - Colombia	5	17	-	10	Urban	Developing

1 http://kcfreedom.net
2 deltalibre.org.ar
3 http://quintanalibre.org.ar
4 http://berlin.freifunk.net
5 http://www.scn.org
6 http://www.awmn.net
7 http://www.wirelessbelgie.be
8 http://www.interlab.ait.asia/ChiangRaiMeshTV
9 http://www.interlab.ait.asia/TakNet
10 http://zenzeleni.net
11 www.firenze.ninux.org
12 http://guifi.net
13 www.sarantaporo.gr
14 http://www.wirelessleiden.nl
15 www.cybermoor.org
16 http://wlan-si.net
17 http://wiki.ninux.org
18 http://www.bogota-mesh.org

Table 2: Replies from several CN contacted: general aspects.

Name	Infrastructure	Membership	Types of Members	Legal Form	Funding	Inet Provision
Kansas City Freedom Network	Wireless Mesh, Wireless Point--to-Pont, Fibre, Wireless Access Points	Community-License Based, Contribution Based	Volunteers, Professionals, Companies, Service Providers, Government	None	Members, Public Institutions, Private Institutions	Uplinks from Tier 2&3 ISPs
DeltaLibre	Wireless Mesh, Wireless Point--to-Pont, Wireless Access Points	Informal, Contribution Based	Volunteers, Professionals, NGOs	None	Members	Uplinks from Tier 2&3 ISPs
Quintana-Libre	Wireless Mesh, Wireless Point--to-Pont, Wireless Access Points, wired ethernet (<100m).	Informal, Contribution Based	Volunteers, Academic	Formal org	Members, current bandwidth is provided free of charge by a company in the local Internet Exchange	Uplinks from Tier 2&3 ISPs, DSL Sharing
Berliner Freifunk Community	Wireless Mesh, Wireless Point--to-Pont, Fibre, Wireless Access Points	Anonymous, Informal, Contribution Based	Volunteers, Professionals, Companies, Service Providers, Government, Academic	None, Formal org, Registered as network/telecom operator	Members, Public Institutions, Private Institutions	Uplinks from Tier 2&3 ISPs, DSL Sharing
Seattle Community Network	on the web or dialup	Fee Based, Contribution Based	Volunteers, Professionals, Academic	A tax exempt 501.c.3 corporation in the US	Members	Through public library
Athens Wireless Metropolitan Network	Wireless Mesh, Wireless Point--to-Pont, Wireless Access Points	Fee Based	Volunteers	Formal org	Members	Uplinks from Tier 2&3 ISPs, DSL Sharing

Name	Infrastructure	Membership	Types of Members	Legal Form	Funding	Inet Provision
Wireless België	Wireless Mesh, Fibre, Wireless Access Points	Informal, Fee Based	Volunteers, Professionals, Companies	Formal Company	Members, Companies who use us for internet access	Uplinks from Tier 2&3 ISPs
Chiang-Rai MeshTV	Wireless Mesh, Wireless Point-to--Pont	Informal, Contribution Based	Volunteers, Professionals, Academic	None	Private Institutions, ISIF Asia and THNIC Foundation	5 Mbps uplink at the Mirror Foundation
TakNET	Wireless Mesh	Contribution Based	Volunteers, Academic	None	Members, Private Institutions, THNIC Foundation	DSL Sharing
Zenzeleni Networks (Mankosi Community Wireless Network)	Wireless Mesh	Anonymous previously. VoIP services only for members of the coop. Fee based, but fee automatically converted into service airtime	A partnership between UWC, the village, local NGO, local school	Formal network and telecom operator	Members, Public Institutions, UWC provided the initial capital, members are covering the running costs	No Internet Provision, Public Phones using VoIP via 3G
Ninux-Firenze	Wireless Mesh, Wireless Point-to--Pont	Informal	Volunteers	None	Members	No Internet Provision
guifi.net	Wireless Mesh, Wireless Point--to-Pont, Fibre, Wireless Access Points	Community-License Based	Volunteers, Professionals, Companies, Service Providers, Government, Academic	Foundation	Members	Uplinks from Tier 2&3 ISPs, ISP and RIPE-NCC member

Name	Infrastructure	Membership	Types of Members	Legal Form	Funding	Inet Provision
Sarantaporo.gr WiFi Community Networks	Wireless Mesh, Wireless Point-to-Pont	Anonymous	Volunteers, Professionals, Academic	Non Profit Organization	Members, European Union Research Programs	DSL Sharing
Wireless Leiden	Wireless Mesh, Wireless Point-to-Pont, Mobile, Wireless Access Points	Informal	Volunteers, Professionals	Formal	Members, Public Institutions, Private Institutions	Uplinks from Tier 2&3 ISPs, DSL Sharing
Cybermoor	Wireless Point-to-Pont, Fibre, Wireless Access Points	Fee Based	Volunteers, Professionals, Companies	Formal	Members, Public Institutions, Private Institutions	Uplinks from Tier 2&3 ISPs
wlan slovenija	Wireless Mesh, VPN over service providers	Anonymous, Informal	Volunteers, Professionals, Academic	None	donations for core infrastructure	Uplinks from Tier 2&3 ISPs
ninux.org Roma	Wireless Mesh, Wireless Point-to-Pont, Wireless Access Points	Informal, Community-License Based	Volunteers, Professionals, Academic	None	Members	Uplinks from Tier 2&3 ISPs, DSL Sharing
Bogota Mesh	Wireless Mesh, Wireless Point-to-Pont	Anonymous, Informal	Volunteers, Professionals, Academic	None	Members, Donations	DSL Sharing, No Internet Provision

Table 3: Replies from several CN contacted: specific organisational aspects.

3.11 Conclusion

Community networking infrastructures have been developed in many locations and communities to address the essential need of citizens to participate in the digital society, to support communication in the artificial digital space as we can do in the natural acoustic space. CNs, as global commons with a central artificial material commons component, are critical enabling infrastructures for the digital world. These infrastructures enable self-provisioned and self-organized ways to build and ensure social interconnection and access to knowledge, content, communication. As the report shows, under common principles, diversity makes a difference, and each CN has created diverse local institutions or organisational structures adapted to local conditions and needs, with different levels of sophistication. Each initiative is adapted to its locality, with slightly different starting points, values, strengths and weaknesses, and diverse levels of development and structuring.

The theory of the commons allows us to look at the design and experiences of several CNs from multiple perspectives. We have looked at resilience and sustainability in a common property regime, its incentives and sustainability mechanisms.

Community Networks have a local impact, ranging from a club (with exclusion) of the initiated in the networking arcane, up to those committed to connect the unconnected and expanding the network infrastructure for all. Scale matters a lot, particularly in an interconnected world that is dominated by large companies in the telecom market. These initiatives create a larger social base to have an influence in governments and law makers. Research activities like this one adds to resilience, sustainability and adaptability.

Given the importance of size and proximity in communities, CNs tend to form decentralized structures beyond the local realm: federated structures or second-layer organizations. In different ways, this is the case of Ninux, Freifunk, guifi.net or INCA CNs. Second-layer organizations allow to aggregate smaller and local initiatives and enjoy the benefits of scale in sharing knowledge, sometimes also governance, services, infrastructure. These aggregate organizations become a visible actor for the dialogue with governments, regulators or other agents as a sector or collective. In addition, CNs are inter-connected, with communication and coordination across initiatives in different regions.

These details and others are further elaborated in D1.2 “Report on Existing Community Networks and their Organization” “(netCommons 2016)” developed as part of the netCommons research project.

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4. Efficient Collaboration between Government, Citizens and Enterprises in Commons Telecommunication Infrastructures

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Public administrations, citizens and enterprises are the three key players for the construction and management of any commons infrastructure. This paper discusses the interrelations between them, under the lens of the ongoing netCommons project, an H2020 research project entirely devoted to multi-disciplinary research on Community Networks (CN). In June 2016 netCommons organized a workshop in Barcelona (Spain), to share views and discuss how these three actors can strengthen ties among them to contribute to the growth of community networks. The workshop analyzed tools ranging from governance strategies and regulation to implementation (at deployment and operation level) of networking infrastructures. Special attention was devoted to optical fiber, a key technology for achieving the coverage and penetration targets of the European Digital Agenda. Based on the experience and the work done so far, the workshop expanded the knowledge about this type of collaboration and identified specific lines of action to make CNs more efficient in the future. The workshop was divided in three panels: governance, regulation, and implementation, with participants from the research field, public administration and practitioners that daily build CNs. We report about the topics discussed and some of the lessons learned during the workshop.

Motivation

For the last century telecommunications has been a key infrastructure for societal development. The traditional model has been public or private enterprises in charge of developing, maintaining, operating the infrastructure and also providing services to customers: all citizens, anywhere in a territory. These infrastructures have been the core of a tussle between three key actors: citizens, companies and organizations willing to communicate, governments and public administrations with the mandate of regulating the public space and the rights of citizens and consumers, and the private interests of the service providers, typically driven by business interests. In the last decade, local initiatives have developed citizen-driven cooperative and self-organized efforts to develop network infrastructures for digital sovereignty and ensure the rights of communication and participation in the digital society: to connect the unconnected, or to provide sustainable and inclusive alternatives. As context matters, in this workshop we have focused on the European scenario and particularly in the scope of Spain and the guifi.net community network. Successive workshops in different regions and community networks will allow us draw a comparison across them.

The aim of the workshop[49] was to build a shared understanding and find ways to optimize the interaction among these three actors, with the ultimate goal of optimizing the development of community networking infrastructures. Based on the experience and the work done so far, the workshop had two concrete objectives: i) expand knowledge about this type of collaboration and ii) identify specific lines of action to make them more efficient in the future. During the meeting these challenges were analyzed and discussed successively from the point of view of governance[50], regulation, and its implementation, dedicating to each block a total of one and half hour with a set of short presentations and one panel session.

This report reviews highlights of the discussions at each session, reflects on what was learned at the workshop, and lists working topics that resulted from it. We appreciate the voluntary contribution of the people and organizations involved. We accept contributions to clarify any aspect of the report that may appear in future versions.

Disclaimer: This report is based on various notes taken during the workshop. It does not purport to reproduce in detail all debates and interventions, that may be imprecise and incomplete. None of the messages

49 http://netcommons.eu/?q=content/workshop-community-networking-infrastructures.

50 Links to videos of each session (with English subtitles for non-English talks): S1 Governance, S2 Regulation, S3 Implementation.

conveyed in this report may in any way be interpreted as stating an official position of the involved organizations.

4.1 Introduction

The workshop was opened by Jordi Via from the Barcelona City Council, as city commissioner in charge of the cooperative, social and solidarity economy (the title, compared to the one used by its predecessors, already implies a change of socio-economic model). Mr. Via highlighted the need to consider sustainability in terms of individuality, society and ecology. According to him, economic activity, beyond the traditional business practices, must include self-organizing community economies to address specific societal needs, going beyond the public-private collaboration also considering public-community. Clearly there are difficulties to overcome, of formal and regulatory nature, but we should not just accept traditional practices as the only immutable normality.

Renato Lo Cigno, the General Coordinator of the netCommons project, from the University of Trento gave an overview of networking infrastructures, the role and achievements of self-organized community efforts, and the interest to understand community networks from a research perspective. He also introduced the netCommons.eu research project.

4.2 Governance of networking infrastructures

The first session, chaired by Maria Michalis from Westminster University, included four short presentations about governance models: a) one general introduction to the commons governance model, b) the telecom infrastructures in Catalonia, c) the optical fibre infrastructure in a mountain region (Garrotxa), and d) the guifi.net governance model.

4.2.1 Communities and the governance of a common network infrastructure

The first presentation by Leandro Navarro from Polytechnic University of Catalonia, introduced and summarized the ideas about commons, and how that applies to network infrastructure commons, with more details in . A commons develops around a resource (the common-pool resource or CPR) that belongs and is managed (self-governed) by a community. The

CPR consists of a core resource which produces a limited quantity of extractable fringe units. In our case, the core resource is the network, which is nurtured by the network segments that participants deploy to reach the rest of the network or improve it, and the fringe unit is the connectivity they obtain.

According to the hypothesis of CPR models, these models, properly managed, maximise efficiency (the product –connectivity in this case– obtained with a minimum amount of resources involved) and ensures long term sustainability (otherwise, they are prone to depletion). These self-regulation regimes deal mainly with non-excludable and rival resources, as self-regulation can promote sustainability and adaptability and prevent congestion.

The commons can be fragmented into different subtypes. Ostrom developed her framework based on the analysis of case studies from local, mostly environmental or natural commons and extended her study with cases from knowledge commons, cultural and digital commons , composed by a resource, a community, legal rules, interaction (commoning), outcomes, evaluation. Scholars further extended this work in an attempt to systematize knowledge commons with another collective volume , infrastructure commons with the example of internet congestion and network neutrality , and internet/spectrum commons .

These extensions of Ostrom's framework look into the nature of the resource, of the community, the criteria of success, failure and vulnerability, and finally it political purpose, in aspects such as the importance of the commons for democracy and freedom. The study of digital commons, with the major examples of free software and Wikipedia, gave rise to commons-based peer production .

The "tree" of the commons has several branches: natural, knowledge and code, and artificial material commons. We look into *artificial material commons* as complex systems where peer production is applied to build some specific, material, resource pool (or system) that is critical for a community as a supporting infrastructure. There is no clear cut between the natural commons and the artificial material commons, but a continuous transition whereby more and more value of the commons is related not to the management of a given natural resource, but to the complex engineering manipulation of the artificial material resource that is built and maintained.

In the past, networking infrastructures were considered a club good (excludable and virtually non-rival as a commercial service) provided by for-profit ISP to those fortunate to be in coverage areas and willing to pay the service fee. Community network infrastructures are a social response to the wide recognition of connectivity as a basic human right, and therefore the network infrastructure connecting people becomes non-excludable, and also rival, as the capacity of a network is limited with respect to the connectivity extracted by its users.

There are different stakeholders in community network infrastructures: volunteers, professionals, public administrations. That leads into different bundles of rights, related to different levels of participation ranging from access for contribution or consumption; management for coordination and decision making; governance for the definition of the regulation; and different coordination mechanisms among participants. Common property regimes seek regulating preservation, maintenance and consumption of the resource, and typically result in agreements, licenses, and stipulations such as conflict resolution or cost sharing mechanisms; rules for access, usage, contribution; structures for supervision and decision making.

In our daily life we often question ourselves about who our devices and our networks work for: Who own them, who feed them, who decides about them, who controls them?. If the answer is not clearly us, then we should think if the digital world where we live is a democracy or a corporatocracy , and how to amend it.

4.2.2 Governments and telecom infrastructures in Catalonia

The second presentation was from David Ferrer i Canosa from the Government of Catalonia, Secretary for the Governance of the Information and Communication Technologies. Mr. Ferrer discussed about important factors from the point of view of public administration, the European Digital Agenda 2020 (DA) as a framework that defines a series of milestones, and how that impacted the development of telecommunication infrastructures in Catalonia. The DA defines that before 2020 all European citizens must have access to at least a 30 Mbps broadband connection and 50% of people must have access to a 100 Mbps Internet access.

He described several governmental mechanisms focused on improving telecommunications services and the availability of infrastructure for these services.

The management agreement for telecommunications infrastructure approved in the end 2014, aligned with the Broadband Cost Reduction European Directive (Directive 2014/61/CE -not yet transposed into the Spanish legal framework), is a policy to reduce the cost of deploying high speed electronic communications networks. It enables that any telecommunications operator may request the use of any infrastructure owned by the Government of Catalonia for the deployment of telecommunication services. The government agreement includes roofs, that enables any mobile operator to locate mobile base stations in any buildings or assets owned by the Government of Catalonia.

Other related projects are Catalonia Connect, launched in 2007, which promotes expanding the coverage of services such as digital terrestrial television. It shows the difficulty of universal coverage: one antenna (Collserola in Barcelona) can cover 65% population in Catalonia. An additional 9 broadcast centers can reach 87%, but 500 more centers would be needed to reach 99% coverage. These locations can support other services such as mobile telephony.

There are sectoral initiatives in fiber infrastructures for the scientific, agri-food, industrial (mostly automobile) sectors. The MEITEL agreement in 2008 that takes into account the deployment of telecom infrastructure in any public infrastructure works.

The Open Network of Catalonia (XOC) is a high capacity open-access network to connect the offices of the Government of Catalonia. The excess capacity generated by this deployment is offered to all wholesale operators (3,800 Km fiber reaching 244 municipalities and covering a potential 5.8 million inhabitants). One important difference in the services provided by XOC, with respect to the incumbent operator, is that XOC services are only rated in terms of capacity independent of distance. This is key to facilitate the deployment and development of telecom services in any covered area at the same cost, therefore supporting the development of infrastructures anywhere. In contrast, the incumbent operator charges differently in terms of capacity and also distance to the largest urban areas. Similarly there's ongoing work to take advantage of the public water infrastructure (Catalan Water Agency) to facilitate the deployment of telecom infrastructures.

Public intervention in Telecom services is subject to strict rules of competition. One mechanism was concession (XOC), another for the access section is the definition of public prices for the rental of space in ducts in public space.

Many aspects of open networks to be improved in Catalonia, and the Catalan government is determined to address them. The main targets are that all over Catalonia we should have availability of high capacity telecom services under equal conditions and at low prices. That should allow alternative operators to deploy infrastructure and services to ensure coverage and compete in terms of service.

The goal of consolidation towards big telecom operators with the intention to compete against the US and Asian operators might have the opposite effect. In Spain consolidation has lead to only three operators, and the three of them have raised prices. That consolidation seems to contradict the goal of a strong market to reach the objectives for 2020 to have equal access in the territory to infrastructures and generate competition. Administrations at all levels (municipalities, regional government, national, European) should engage in guaranteeing access to infrastructures with competitive pricing that promotes competition and competitiveness of these services.

4.2.3 The guifi.net governance model

The third presentation was from Roger Baig Viñas from the Fundació Guifi.net. He introduced a community networking perspective, developed from the experience of guifi.net. Like other community networks guifi.net is a citizens' initiative. There are different business models to develop networking infrastructures, and he presented the guifi.net model. The model is based on the principles and practices of commons collaborative economy, the common pool resource (CPR) governance model, the commons, and sustainable design.

He described a layered functional model of telecom services: the passive layer, the infrastructure operation layer, and the service layer that provides the services people use. There are different models to regulate the competition for the different functions: with different actors for each layer (functional separation), actors covering two or the three layers (vertical integration). guifi.net proposes a commons format, a cooperative model to develop an open, free and neutral network infrastructure, for the lower two layers, with services provided by multiple actors, either professional or voluntary-based.

guifi.net started in rural areas, in the mountains, and eventually reached Barcelona, where traffic exchange is performed and international carriers arrive.

guifi.net is about managing a communal infrastructure, with multiple stakeholders and roles. Governments are in charge or organizing the public space and the rights of citizens, such as access to basic internet services. There are professionals providing services offering service guarantees in exchange of service fees. There are volunteers that can participate in all aspects of the network. This has some requirements in transparency and participation process, since we can not build a commons without being open and transparent.

Several tools have been developed: the community license defines the rights and obligations of the participants. It is a viral license: anyone who enters the network must accept and it basically says: "since I could enter the network that was open free and neutral, I can not deprive others to use my network node to join the network". From this license we build all the other tools that we need to govern ourselves.

Sustainability is critical in a commons. Well-governed economic activity will produce resources that will allow us to be sustainable. We must ensure that a part of the profit of those who are taking advantage of the common good is reinvested in it, so that the common good will not die. Stakeholders should understand that re-investment is good for them because otherwise the common good will be depleted. This is the economic compensation system, where CAPEX and OPEX costs are compensated among participants in an area. This is calculated from costs to return the investment, so it is not a price agreement to limit competition (collusion) but to promote the sustainability of a commons resource and promote participation. This is described in more detail in .

In guifi.net we bring the concept of commons in telecommunications infrastructure through a commons and collaborative economy. We believe that our model is disruptive with facts, and not only words. We have proven that this works and we're working on it every day, and every day we grow. This is necessarily transparent and non-discriminatory. It is also efficient because now we know the costs. Participating in all this we have also learned what things are worth and their detailed real costs. We are a case of good practice and we are also internally detecting best practices which lead us ever more to consolidate this. It is totally organic and something essential: it is not speculative.

4.3 Regulation and legislation

The second session moderated by Melanie Dulong de Rosnay, CNRS, aimed at better understanding the legal surrounding of CNs, with four presentations on the hurdles created by regulation for CNs in Europe, on the legal framework the administration has to implement for operators in Spain, on a commons-based model of infrastructure sharing allowing cohabitation between all actors, and finally on a local experience of implementation.

4.3.1 Regulation and Community Networks

The first presentation was by Félix Tréguer, CNRS and netCommons.eu. He described specific cases where regulation may inadvertently be creating hurdles for CNs, by excluding CNs from public networks. He also discussed ways of lifting unnecessary regulatory burdens, such as promoting open Wi-Fi. For instance in the 2012 EU Radio spectrum policy program, there is a mechanism where member states in cooperation with the Commission can use unallocated spectrum for developing mesh community networks. He suggested offering direct public support to these digital inclusion initiatives and at the same time inviting CNs to the policy table.

4.3.2 Legal aspects in Spain

The second presentation was by Olga Díaz, Head of the Legal Department in the Localret Consortium. She focused on defining the regulation framework or ``corset', and the need to interpret or in some cases modify (by the ministry and regulator) the rules for public administrations in a) operating or providing service (operator), and b) regulating the use of public space.

An administration should act under the principle of private investor when considering the initial investment, its return, and expected performance such as private investor.

In the first case of service provision: if the public administration yields to a private operator to exploit an infrastructure, then the administration becomes anyway an operator from the legal perspective.

The "Electronic communications networks" mentioned in the 2014 telecom law, regarding services to the public (not just internal or self-service), does not consider the public works such as ducts, pipes as ``communications network". However, even though the 2014 law regulates this, details are not yet developed.

The 2014 telecom law restricts public admin beyond what is considered self-service for their workers (which does not force them to become an operator). It also includes libraries (Internet access) and schools, including internet access telecenters in public schools.

Establishing a public administration as an operator has to be done through setting up an operator as a separate company. It must respect the rules as private operator in that it should not affect competition (e.g. with free-of-charge services). It should also consider market failures (if they are present, a public administration can then provide services). Private operators should have access to this infrastructure.

According to some cases investigated by the competence regulator (CNMC report), open Wi-Fi Internet access provided by public administration in public places to the public, limited to 256kbps, is not considered anti-competitive .

Regarding regulation of access to the public domain, operators can occupy public space. Tenders are prohibited since everyone can get access on equal terms. Pipes, poles, etc. are supporting elements to which administrations need to facilitate access. This can not be done exclusively and should be on an equal footing, according to Art 37 of the Spanish Telecom law . Local authorities should allow the usage of lamp posts, buildings, etc. in the same conditions as these are provided to private operators. However, if an entity is introducing a communications element, even a passive fiber, it becomes an "Electronic communications network", and then the public administration should be constituted as an operator.

In summary, public administrations should work under a) the principle of neutrality (equal terms, competition) with respect to regulating access to public space by operators, and b) under the principle of private investor when being involved in providing any service, to respect market competition (unless there is a "market failure" situation or the service is less competitive i.e. limited in speed or other ways).

4.3.3 Fibre infrastructure in a mountain region (Garrotxa)

Francesc Canalias i Farrés, Director of the Consortium for the Environment and Public Health of Garrotxa (SIGMA) shared his experience of infrastructure deployment in a rural area[51] with a large natural park, about 25,000 inhabitants, and also several industries.

The model is based on an initial investment (and initial deployment) that is contributed by the public administration, and later on recovered from the private entities that connect to the network infrastructure. That seems a feasible model helping to accelerate the availability of network infrastructure in that area.

4.3.4 A community networking perspective

The fourth presentation was by Ramon Roca i Tió, President of the Guifi.net Foundation. He explained how electronic communications or telecommunications are services with an increasing effect on society in general, affecting all areas from the formative development of people and leisure as well as areas of economic production and business. They are also a pillar for supporting intelligent public services. Accelerating the existence of the

51 https://en.wikipedia.org/wiki/Garrotxa

best technology offering at the best possible cost is therefore a key factor in the development of our society and public services and of the competitiveness of companies in the territory.

Roca described the "Universal Format" infrastructure deployment model as generic (for all possible uses and for all business models, not enforcing or discriminating any specific). The aim is to adapt the new European and state regulatory framework at a local level in a clear and stable way in order to:

1. Comply with European directives and the applicable legal order at the level of the state and Catalonia, while developing competences that are typical of municipalities in the related issues, and ensuring transparency and non-discrimination.

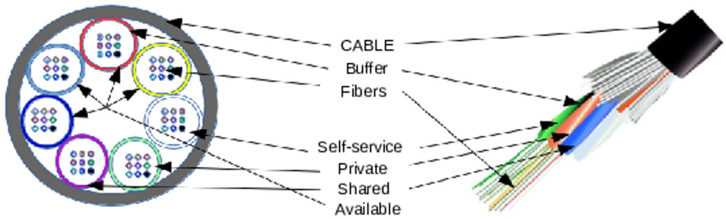
2. Facilitate the deployment of access networks to next-generation telecommunications services with the maximum possible speed and efficiency, stimulating and ensuring the efficiency of investment, while ensuring its sustainability based on use and minimising the cost to the public administration and citizens and society, in general.

3. Facilitate the deployment of the necessary connected infrastructures (sensor devices, etc.) to develop new and better smart public services (lighting, waste management, security, mobility, etc.).

4. Provide access for citizens and society in general to a varied and affordable offering of telecommunication services of the highest quality and capacity, regardless of location, without conditional business models that develop from the private sector, ensuring its diversity and avoiding market dominance situations or speculation that would harm that diversity.

The scope of application is regarding the competence of the city council related to the infrastructure capable of hosting next-generation telecommunications services or its components.

In short, the government should facilitate access to these infrastructures in objective, transparent, and non-discriminatory conditions, never in an exclusive or preferential manner for a determinate operator, forbidding the granting of access through tendering procedures, and according to the existing regulatory framework.



The Universal format for fiber cables

Deployment in Universal format is deployment that simultaneously allows for the three classes of uses (self-service for the city council, private, and shared or common use). To do so, a cable (with several buffers, buffers with several fibers) is divided into three parts, one for each use. At the start, each part has a minimal structural unit. The rest of the free structural units will be available for upgrades for those who need them, and who have irrefutably proved that they have exhausted the initially reserved capacity. See the figure [fig:univf] for an example of the initial distribution of the reserves of use of an optic fiber cable in three parts (self-service for the city council, private, and shared), using fiber tubes as the minimal structural units.

This model has been developed as a template for a municipal ordinance. The purpose of this ordinance is to serve as a basis for municipalities to regulate the deployment of infrastructure that could be used for advanced networks, which is the responsibility of the city council.

4.5 Implementation: Challenges in carrying it into practice

The third session moderated by Leonardo Maccari, University of Trento, aimed at raising the challenges in deploying and managing network infrastructures from the experience in specific cases. There were four presentations from different scopes: European broadband infrastructures, public financing from the European Commission, Barcelona from the City Council, the guifi.net Foundation in Spain.

4.5.1 European Broadband infrastructures

Wolter Lemstra, Senior Research Fellow at the University of Delft, described an analysis of the development of broadband network infrastructures in Europe . The whole European communication panorama started with a very vertical market,in which each country was dominated by a single public incumbent. The market was then privatized, transforming the incumbent into private companies, and trying to make them compete with newcomers, which should have made it possible to create a wealthy single European market. Even under these premises we have to observe that technologically, the starting point of each state is different from one to another. In many countries the legacy telephone lines were ubiquitous, but not, for instance in new member states, which are today jumping to high-speed cellular networks. Or, in some countries cable TV was present, while in some other it was completely absent. This already suggests that the idea of a single European market should not lead to think of a single technology for broadband connectivity. Since there is nothing like a single trajectory from zero-bandwidth to high-bandwidth, there is space for different approaches, that may well generate from non-Telco actors.

A lot of bottom-up initiatives, which we may not be aware of, because they are not called “community networks” explicitly are spread around Europe. Some of them are no-profit, some are small local companies, every one apparently tried to adopt the right organization to succeed in its own environment.

The difference between a Telco and a non-Telco approach, is generally in the more proactive approach that the latter offers. Bottom-up initiatives tend to mobilize people, whether they are small business, municipality initiatives or community initiatives to reach a core of people that can open a new market or enforce a non-market solution. As we have currently recognized that market alone fails to bring universal access, the public administration and the government also have to give incentives for these bottom-up initiatives to flourish.

One of the open issues that community broadband initiatives have to face is the step that leads to scalability. Bottom-up broadband initiatives often start at a small scale to solve the problem of a small community of people. In some cases they become large scale initiatives, some of which have been recently documented .

4.5.2 Public financing of European infrastructures

Fabio Nasarre, and Laure Blanchard-Brunac from the European Commission discussed the access to financing instruments in this field in the European panorama. The European Commission is offering several financial instruments that the Commission makes available to let bottom-up broadband grow, including:

- Connecting Europe Funds (CEF) 1B€ from which 150M€ for pilot projects to make them more bankable.
- Junker plan: 21B€ managed by the European Investment Bank (EIB) in Luxembourg.
- The EC refers to EIB to finance projects. The European Fund for Strategic Investments (EFSI) is a joint initiative of the European Commission and the EIB Group, the Plan will unlock investment of at least EUR 315bn€ over three years.

Some of these initiatives are accessible from small organizations and are not necessarily tailored to large Telcos and corporations. The presence of these initiatives confirms that the European institutions recognize that there is a space for bottom-up initiatives that can fill the gap left open by the market failures. Many details were given about the procedures and the entry point to start one such procedures. There are challenges for the digital section in preparing projects that can be supported by banks (bankable). The EIB/EC highlighted a one-stop shop advisory Hub: they'll provide advise, mainly in financial aspects. From the 1st June there is a web site where Platform promoters can publish projects, investors can see them[52].

4.5.3 The City Council and Barcelona

Francisco Rodríguez Jiménez, from the City Council of Barcelona, shared his view about Barcelona, like most large cities in Spain are covered by multiple operators and therefore there is a market, although there are studies that show room for improvement in the available capacity in certain neighborhoods and areas. The city has a corporate fiber infrastructure of more than 500 Km, where the infrastructures are open in equal terms to telecom operators. In 2004 a WiFi infrastructure was started, which required a negotiation with the telecom regulation authority. In the "22@" area there is a neutral infrastructure fiber operator. Municipal conduits can be used by other operators through agreements but also exploring the use of the urban furniture by third parties.

52 http://www.eib.org/eiah/

4.5.4 The guifi.net deployment model

Lluís Dalmau i Junyent from the guifi.net Foundation presented the approach of guifi.net for the deployment and maintenance of network infrastructures. We have also to recognize that a key point that distinguishes the for-profit approach from the bottom-up commons approach is not only the financial aspects, but, and most notably the way the resources are organized, shared and managed. Under this point of view the experience of Guifi is probably the one that produced the most in-depth analysis of the “commons” concept and its application to networks. Guifi, interpreted Ostrom principles and translated it into and the transparency [NOT CLEAR] , definition of roles and a compensation system that accumulates information about expenditure (CAPEX and OPEX) and resource consumption (usage).

4.6 Discussion

There are multiple organizational models to develop a networking infrastructure. Beyond the traditional commercial model (investor and profit driven, extractive for the target service consumers), there are commons-driven models that can develop community infrastructures in a cooperative, cost sharing, and self-organized manner. Diversity of models contribute to ensure the availability of connectivity, the development of sustainable networking infrastructures and ultimately boost local socio-economic development. It has parallel features to free software, that create viable alternatives, is developed cooperatively, and can create opportunities to develop higher added-value in the volunteer, in the professional or commercial sector too. Cooperative models have developed ways to create economies of scale (grouping individual entrepreneurs and professionals sharing risks, aggregating costs, sharing infrastructures), create economies of knowledge and tools (sharing the effort to develop know-how, procedures, software tools and services).

Public administrations (city councils, municipalities, and governments at all levels) have the responsibility of regulating the offer of networking services to citizens, the occupation of the public space, preventing discrimination: towards citizens under objectives of fair (universal) service to ensure communication rights, and towards network operators to ensure market rights. Competition should be preserved when available, but the role of public administrations is also to promote the offer or alternatives in cases of “market failure” including public investment. However these interventions should be under the principle of the public administration acting as a “private investor”. In any case the regulation of occupation of public space can coordinate all interested parts under the principles of minimizing cost and impact in that occupation. The Universal deployment format is a proposal for the regulation of the deployment of networking infrastructures for advanced networks through infrastructure and cost sharing.

Coordination mechanisms among private and public organizations, and citizens can help to accelerate the development of sustainable networking infrastructures, for the benefit of all parts and society in general. Different organizational models (e.g. firm, commons, extractive, collaborative), cooperative and competitive schemes, coordinated and regulated by public entities, allow commercial and community operators to develop and ensure everyone can best participate in the digital society.

While most of the ideas are universal, the details can vary across continents, countries, regions, and municipalities. Further work is required to develop universal ideas and generic mechanisms in the light of the local specifics, such as the needs of its inhabitants, geography, history, legal regime, regulation, and other social, economic and environmental factors.

4.7 Acknowledgment

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4.7.1 Discussion 1

Two questions, both with respect to the involvement of local municipalities to the effort and their support, also from policy point of view:

First question from Wouter Tebbens (Free Knowledge Foundation) on how the authorities think about joining and supporting the effort, “it is difficult to start always”

the reply from the Secretary has been that the municipality can do this for passive network equipment, not “active” (and they see guifi as one providing active service, with implications for adherence to competition rules)

the second question (Marco Berlinguer) called for taking into account that the market rules do not really hold anyway – the markets in most countryside areas are monopolies.

Roger: “at first hand, we ask for equal treatment, i.e., get the right to use ground and terrace for the deployment of equipment”

4.7.2 Discussion 2

Two important issues raised:

We have to be more attentive to gender issues. Only one woman was among the speakers. We will have to rebalance this in future workshops.

Ostrom principles deal with the definition of successful commons experiences, more research has been done in the following to describe the governance of such commons and in particular, of digital commons. I think the reference that was given is the following one: Governing Knowledge Commons, Brett M. Frischmann, Michael J. Madison, Katherine J. Strandburg

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5. Community Networks: Legal Issues, Possible Solutions and A Way Forward in the European Context

Federica Giovanella

This paper largely draws on some previous works including F. Giovanella, 2015b and R. Caso, F. Giovanella (2015).

Abstract

This paper analyses the existing rules on civil liability and considers their applicability on Community Networks (CNs), based on the European framework on electronic communications. In particular, the paper focuses on tort liability for three different actors: CNs' users; ISPs, for the case of shared Internet connection; and CNs themselves, and it describes the different situations to which civil liability should be applied in relation to the three mentioned actors.

As the analysis demonstrates, the structure of CNs seems irreconcilable with the aims of current legal framework for tort law. The paper tries to imagine possible steps to be taken to allow a reconciliation between CNs' prosperity and the needs of law. Final remarks will include also possible paths that policymakers should follow in order to foster the diffusion of CNs.

5.1. Introduction: Community Networks

The aim of this paper is to analyze how the current framework for civil liability applies to CNs and to sketch possible policy actions to be taken, in order to reconcile CNs' potentialities with the needs and aims of tort law. This first paragraph illustrates the main characteristics of Community Networks (CNs) in order to allow the reader to understand the links and the respective effects between CNs and civil liability law[53].

Broadly speaking, CNs can be described as distributed architectures in which users implement a physically decentralized network through the decentralization of the hardware[54]. Community Networks (CNs) vary in scope, coverage, aims, management, and so on. Nonetheless, I will here refer to CNs as a single category, to allow a better comprehension of the phenomenon. CNs, which in the majority of cases are wireless ones, are networks organized through a bottom-up approach, whereby people who identify themselves as a community create a self-managed and community-based network. These architectures are normally used for users' interactions, such as for messaging or sharing of data. However, they are mainly famous for another feature, namely: bringing Internet connectivity to locations where it is unavailable. In those places where Internet Service Providers (ISPs) do not offer their services, for example where it would not be profitable, a CN can be an alternative to obtaining an Internet connection.

Very often, these networks rely on "wireless mesh networking" technology. In this case, a Wireless Community Network comprises nodes that both generate data and route other nodes' traffic. The structure of these networks, made of stand-alone devices, permits the connection of thousands of nodes. When a node is connected to the Internet, the entire network can potentially surf the Internet; this is possible since data travels from one node to another and can reach the "connected node". Through that node – known as "gateway node" – and with the consent of that node's owner, other users can access the Internet.

The bottom-up approach characterizing CNs mirrors in the absence of a hierarchical organization. Many of these networks also lack a central administrative body with control or representative powers[55]. Each user is responsible for her own node: the network is simply a spontaneous community-based structure.

53 When I refer to "civil liability" I consider those situations where a damage is the consequence of an illicit behaviour, whenever there is no binding contract between the wrongdoer and the victim of the damage. Think for instance about cases of copyright infringement, of defamation, of privacy breach.

54 The idea of a decentralized network was key in creating the Internet: a computer network without any central node would have been more resilient to possible attacks. However, the Internet then evolved in a different way, as today it is infamously clear that it mainly relies on few operators and on big nodes. Cf. Elkin-Koren, 2006, pp. 20-21.

55 Some networks are instead represented by an association or a foundation; this is the case, for instance, of Guifi.net – the network of Catalunia: http://fundacio.guifi.net/index.php/Foundation.

A final feature worth mentioning is the high level of anonymity: even though each node has an "Internet Protocol" (IP) address, users choose their own IP address and can change it at any time. In addition, there are no databases in which these IP numbers are registered, contrary to what happens in the Internet environment where ISPs store these data. Some CNs keep track of the modifications in IP addresses, as the Italian network "Ninux.org" does. However, the way these changes are recorded is unreliable, as user can modify the prospect where the IP addresses are registered. As the prospect cannot be considered highly reliable, even in the case that an IP address is known, it would be almost impossible to identify the person who was using that number at a given moment. In addition, anonymization software or encryption techniques are very often implemented.

Most communities have neither written norms regulating relations amongst users, nor a central authority. CNs usually rely on "manifestos", such as the "Picopeering Agreement"[56]. More structured CNs, such as Guifi.net – the network of the Catalan region[57], implemented other regulatory tools, such as the "Compact for a Free, Open & Neutral Network" (FONN Compact), a license binding both the network and the users[58].

Based on the just described features of CNs, the next section will analyze the different situations to which civil liability should be applicable according to current rules, in the European context. The last section will finally try to envision possible steps to be taken in order to allow a reconciliation between CNs' prosperity and the needs of law.

5.2. Liability Issues in CNs

The structure of CNs constitutes an obstacle to the application of the existing laws or, at least, to the way we have always applied them. For instance, distribution often implies the fragmentation of conducts: a single conduct can be allocated to a high number of different users' machines. This makes it difficult, when not impossible, to define who committed or contributed to the commission of a specific action (Dulong de Rosnay, 2015). This depends also from the fact that the IP addresses of the people taking part to these networks are undetectable or, at least, very hard to match with the real identities.

56 http://www.picopeer.net/PPA-en.shtml.

57 https://guifi.net/en.

58 https://guifi.net/en/FONNC; see in particular S. "II About this document (FONN)".

As above mentioned, this paper concentrates only on civil liability matters, which will be briefly explained in this section. Following CNs' description, three different cases can be envisioned, each involving a different subject: the user, the ISP, the network (Giovanella, 2015, pp. 52-63).

A user could be held liable for her own conduct or, if routing another user's information, be considered jointly or indirectly liable for the action of the other user. In this case, ordinary rules of civil liability of each European state would apply, such as art 2043 of the Italian civil code, § 823 I of the German *Bürgerliches Gesetzbuch* (BGB) or the general "tort of negligence" or other specific figures of tort law in the English system. In the second situation, general clauses of civil liability will be applicable along with those providing for joint and several liability[59]. In both cases, to enforce the infringed right, the first step would be to identify the person behind the screen, *i.e.* the owner of the node from which the wrongful action came. However, if we consider what above said on anonymity and IP addresses, the possibility of identifying the wrongdoer diminishes considerably. As a consequence, there would be no legal protection for the victim.

The classical and most straightforward approach would be to act directly against the final user; however, from a technological point of view this solution seems unfeasible.

A partially different case would be one in which the wrongful action took place through the gateway. In such a case, could the ISP be held liable for the user's wrongful behavior? At a European level, Directive 2000/31 on Electronic Commerce and its national transpositions would apply[60] . According to the Directive, if the ISP complies with the specific conduct required of it by the law, it will not be held liable for a third party's wrongful action. The Directive subdivides ISPs' activities into three different categories: mere conduit (art. 12), caching (art. 13), and hosting (art. 14). The three activities entail an increasing level of involvement by the intermediary; this implies, for example, that it is generally more difficult for a hosting ISP than for a mere conduit ISP to be exempt from liability in relation to a user's wrongful behavior.

Articles 13 and 14 of the Directive define "caching" and "hosting" providers; both are held liable for the activity of storing information (albeit in different ways) upon the request of a user, and for not removing the

59 See art. 2055 of the Italian civil code; § 830 I of the BGB; the English Civil Liability (Contribution) Act of 1978, sec 1(1).

60 Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market [2000] Official Journal (OJ) L 178, 17.7.2000, 1–16. About ISPs' liability see: Julià-Barceló and Koelman, 2000; Baistrocchi, 2002; Verbiest et al., 2007.

information when required. The Directive imposes liability on a caching or a hosting ISP irrespective of the source of the information. Therefore, in the case of CNs, it would not matter whether the information that must be removed comes from the user owning the node or from another user within the network.

A different situation concerns "mere-conduit" providers, defined by art. 12 as providers whose service consists in "transmission in a communication network of information provided by a recipient of the service, or the provision of access to a communication network". These providers are usually bound to their customer through a contract. Hence, besides the hypotheses in which the Directive's exemptions apply, a provider could limit its responsibility by means of specific contractual provisions, for instance introducing a prohibition to share the connection, as many providers already do [61]. When such a clause exists, the customer/node-user that opens her node to other peers will thereby breach the contract. In addition, the customer could also be considered liable for the damages suffered by the provider as a consequence of the illicit conduct committed through the gateway (Mac Síthigh, 2006; Robert *et al.,* 2008; Giannone Codiglione, 2013). Such a situation would constitute a deterrent to sharing the connection.

In addition, the gateway node/user can be identified since it has public IP address[62]. Depending on national laws, the user could or not be sued for third party's conduct[63]. In fact, some European countries consider leaving a Wi-Fi connection open to strangers tantamount to act negligently, given a specific duty of care on the gateway-user. This is the case of the French law "HADOPI" that requires Internet subscribers to make their Wi-Fi connections secure by means of passwords, in order to avoid incurring in liability for third parties' infringement of copyrighted works[64].

Germany has recently changed its attitude toward "open Wi-Fi". Indeed, following the 2010 *Bundesgerichthof*'s decision "Sommer unseres Lebens" a private person who failed to secure her connection through a password enabling third parties to infringe copyright could be considered as an indirect infringer[65]. However, in the summer of 2016, the German law

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61 On the other side, see the list of wireless friendly' ISPs in the USA by the Electronic Frontiers Foundation: https://www.eff.org/pages/wireless-friendly-isps.

62 On the hurdles of matching an IP address with a "real identity" consider F. Giovanella 2015a.

63 Taking Italy as an example, the current framework for tort law would not allow to place liability on the gateway node for the activity of the user, since there are not general clauses on third-party liability (Giannone Codiglione, 2013, pp. 123-135).

64 French Intellectual Property Code art. L. 336-3, as amended by art. 11, Loi n. 2009-669 of 12.06.2009.

65 Bundesgerichthof, Decision of 12.05.2010 - I ZR 121/08, Sommer unseres Leb-

on telecommunications was amended to clarify that a private user cannot be held liable for "open wireless". Similar discussions have been ongoing in UK with regard to the "Digital Economy Act"[66].

As for Italy, while in the past professionals running Wi-Fi connection business had to identify each and every person using the network, currently these duties do not exist anymore[67]. Quite the contrary, in 2013, the government adopted a decree that aimed at liberalizing Internet access through Wi-Fi technologies[68].

On September 15, 2016 the Court of Justice of the European Union decided a case involving Wi-Fi sharing [69]. The facts of the case are quite simple: Tobias Mc Fadden owns a shop where he also runs a wireless local area network (WLAN) that is open to the public. In September 2010, someone made a song available through that network, without the consent of the copyright holder, Sony Music. Sony sued Mc Fadden asking for compensation for indirect infringement for not having secured his WLAN, as decided in the mentioned German Supreme Court's decision "Sommer unseres Lebens". Mc Fadden brought an action to obtain a negative declaration and, as a response, Sony asked for an injunction against Mc Fadden.

The Court of Munich referred to the CJEU many questions. However, only two seems to me to be important for CNs' development. The first is the interpretation of art. 12 of Dir. 2000/31 and its applicability to professionals that, as an additional activity to their main business, operate a wireless local area network with Internet access, accessible by the public free of charge. The second question is instead related to the injunctions that could be ordered against such a professional and aiming to stop copyright infringement, asking what measure would be the most suitable.

Advocate General Maciej Szpunar, in his opinion of March 16, stated that the definition of "service normally provided for remuneration" should be interpreted in a broad sense[70], including connections offered within the economic context of a bigger business . Hence, such connections should

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ens.

66 Consider the public consultation promoted by Ofcom (Independent regulator and competition authority for the UK communications industries), at: http://stakeholders.ofcom.org.uk/consultations/infringement-implementation/?a=0.

67 These duties had been imposed by decreto legge 27 July 2005, n. 144, that had temporary effects and was not extended after the end of 2011.

68 Decreto legge 21 June 2013, n. 69. The same decree also clarified that when supplying an Internet connection is not the main activity of the provider numerous administrative requirements do not apply.

69 C-484/14, Tobias Mc Fadden v. Sony Music Entertainment Germany GmbH, September 15, 2016.

70 Opinion Advocate General Szpunar, C-484/14, Tobias Mc Fadden v. Sony Music Entertainment Germany GmbH, 16 March 2016, parr. 34-50.

benefit from the exemptions provided by Dir. 2000/31[71]. This reasoning is easily applicable to CNs that include in their services the supply of Internet connection to final users, such as Guifi.net. Advocate General also specified that the imposition to make Wi-Fi network secure by means of a password does not strike a correct balance among the different rights at stake[72], namely: freedom to conduct a business, freedom of information, right to protection of intellectual property. In fact, password-protecting a network would negatively affect the two mentioned freedoms, without granting certain results against copyright infringement. Advocate Szpunar also maintained that such an imposition could have collateral, even if not direct, effects on the sharing of private connections; it would impair innovation and have a negative impact on society as a whole[73].

The Court of Justice took instead a partially different position. In particular, while the Court agreed with Advocate Szpunar that art 12, Dir. 2000/31 can be applied to cases such as Mc Fadden's one, its reasoning was diverse on the question of injunctions. The Court considered password-protecting the network as a valid measure that could strike a fair balance among rights, provided that users identify themselves before obtaining the password. The Court explicitly said that people should not use these networks anonymously.

The impact of this decision is yet to be seen. However, a few remarks can be made. In case a CN's gateway node is owned by a business, this gateway could be considered as an intermediary and therefore enjoy liability limitation under Dir. 2000/31. However, it could also be the target of injunctions. Other situations, such as private individuals sharing their connection, are not influenced by this decision and remain a matter (only) of Member States' law.

A final possibility should be evaluated: could liability be imposed on the same CN for the wrongdoings committed inside the network? A first remark is necessary. As mentioned, CNs originate within communities as self-organized and spontaneous ways of communication. They are not incorporated as companies; they do not even have a clear structure, with a person in charge of the community or the network who could be considered liable in case of wrongful actions. Many of them do not have a "legal personality" and it would not be possible to sue them. Furthermore, they do not have economic capacity to pay victims' damages.

71 Opinion Advocate General Szpunar, spec. par. 57.

72 Opinion Advocate General Szpunar, cit., par. 147. The necessity that a fair balance is struck between different rights at stake can be found in C-275/06, Productores de Música de España (Promusicae) v Telefónica de España SAU, January 29, 2008.

73 Opinion Advocate General Szpunar, parr. 134-150

A different scenario would exist for those CNs that organize themselves as (or are run by) foundations or associations, as Guifi.net. Foundations and associations shall normally have a legal representative, such as a committee or a president, who could be held liable for the actions of the members. Even though this depends again on each country's system of laws, normally foundations and association (must) also have financial assets on which the whole activity is based.

Nonetheless, a dedicated contract could shield the foundation/association from liability. This is again the case of Guifi.net. Its FONN Compact explicitly includes a section devoted to "Security and Responsibility", which states that the "open network is not responsible for any damage a user may suffer during its use" and that "each user is responsible for his use of the network, the contents he contributes and his act"[74]. Hence, although the foundation could hypothetically be held liable for users' wrongful conducts and pay for damages, the FONN shifted risks to the same users accepting its conditions.

Considering CNs as communities of people, a final hypothesis could be to apply joint and several liability to all of those who participate in the network and in its activities, as if they had all contributed to the wrongdoing. However, not only it would be highly difficult to understand who contributed to what, it would also be impossible to trace users, as above explained.

5.3. Possible measures to be adopted

It follows on from what just explained that ordinary rules for civil liability cannot be enforced due to the inherent structure of CNs. Considering that CNs are spreading all over the world, specific policy actions should be considered in order to allow their prosperity, especially in developing countries.

The most straightforward way to allow enforceability would be to introduce an identification system for users. However, this would clearly have a chilling effect on free speech. Such a negative outcome shall be carefully avoided, especially in countries where freedom of speech is hindered for political reasons.

Another possibility would be to introduce a specific liability regime for CNs. However, this would require them to have a legal status, for instance to be organized as associations or foundations. This would in turn

74 "VII About Security and Responsibility" of the FONN Compact, cit.

let the CN bearing the entire responsibility for users' illicit actions, as the latter could literally hide themselves behind their monitors[75].

Being these the hurdles that law should overcome, an important point should be stressed: the actual structure and functioning of CNs might be different from what previously explained. Studies in engineering show that some nodes are "bigger" in terms of data routing, with the consequence that the networks are not as centralized as they should (would) be (Maccari, Lo Cigno, 2015). When such critical nodes are also connected to the Internet as gateways, they can be identified through their IP address. This clearly makes the networks weaker: in case one of these nodes is shut down, the entire network is affected. The same holds true also in case a node shall be shut down as a consequence of a legal action.

Hence, policymakers should probably consider different tools. First, lawmakers should encourage the adoption of codes of conducts. As mentioned, CNs usually rely on tools such as the Picopeering Agreement or the more complex FONN Compact of Guifi.net. At the base of these "soft regulatory tools" there is the idea that people joining the network are motivated and share the common principles of community participation and knowledge diffusion. If a user breaches the rules, there are ways to exclude her, for instance cutting her connection or ceasing the agreement[76].

Lawmakers should consider these tools as a starting point and encourage the adoption of more detailed codes of conducts. As users give high importance to the network, it could be possible to introduce an informal monitoring system implemented by users. Users themselves could monitor their peers and signal the presence of suspect conducts. This could also be coupled with the implementation of internal filtering systems; for instance gateway nodes could function as filters for the data that other users try to send to the Internet.

This kind of approach would require a careful study of the functioning of the community and of its social norms and its effectiveness would have to be tested [77]. Guifi.net and its FONN Compact are an inspiring example of how to manage a CN through a contract[78]. The FONN contains specific clauses that shield Guifi.net's liability for users' wrongful actions and it provides a specific dedicated means to resolve conflicts concerning the interpretation and application of the FONN itself. Such a conflict resolution

75 For a more comprehensive explanation: Giovanella, 2015b, pp. 63-67.

76 See "X About Conflict Resolution and Jurisdiction", n. 3, of the FONN Compact, cit.

77 Uncertainty remains: even though this approach could reduce the probability of wrongful conduct, the same problems highlighted above would nevertheless occur any time an illicit action is committed within or through a CN.

78 For details:

system strengthens the FONN and allows its enforceability at an internal level and not only before national courts[79].

The adoption of a license such as the FONN would in the end need the community to organize as an association or a foundation, to obtain legal personality. However, it would be a useful tool to regulate liability issues for the CN, in order to preserve it without compromising its core, positive features, especially when the size of the CN is increasing.

Whatever the solution adopted, the main challenge will be balancing the protection of the network with the protection of individuals' rights. This is relevant given that CNs are recognized as representing a remarkable tool to foster democracy, especially in developing countries, where these networks are gradually diffusing.

The future might or might not bring cases involving the liability of CNs. But if there might be cases, it will be necessary to understand how best to balance these apparently irreconcilable needs for protection.

5.4. Policy Suggestions to Enhance CNs' Diffusion

A part from the questions related to liability, policymakers should start considering the adoption of regulations that could foster CNs. More precisely, lawmakers should implement specific laws and exceptions thought for CNs, in order to enhance their prosperity.

Let us consider two examples. The first is related to the so called "Radio equipment Directive" of 2014[80]. The Directive harmonizes existing regulations on radio equipment with the aim of improving security and protecting health and safety. According to Recital 16, "[t]he compliance of some categories of radio equipment with the essential requirements set out in this Directive may be affected by the inclusion of software or modification of its existing software. The user, the radio equipment or a third party should only be able to load software into the radio equipment where this does not compromise the subsequent compliance of that radio equipment with the applicable essential requirements". The text of the Directive has been read as a threat to free software and, in turn, as a threat to projects like CNs[81]. In fact, CNs usually rely on hardware (routers) run through

79 See "X About Conflict Resolution and Jurisdiction" of the FONN Compact, cit.

80 Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance.

81 See the Free Software Foundation statement: https://fsfe.org/activities/radio-

open software that allow the creation of mesh networks. Art. 3 of the Directive requires manufacturers to adopt software compliant with existing national regulations; manufacturers – as well as importers and distributors – are responsible for the compliance of radio equipment with the Directive. Hence, they will probably make it very difficult for users to modify internal software, as to avoid incurring in this responsibility.

In spite of the fact that the Directive's targets were clearly not CNs or similar projects, the former might nonetheless have a negative impact on the latter. Therefore, when implementing regulations that can potentially impact on CNs, lawmakers should take into account also the needs of these networks, in order not to impair their diffusion[82].

The second example concerns what above narrated on Wi-Fi sharing and liability. Policymakers should consider adopting ad-hoc statutes or exceptions allowing the prosperity of CNs. For instance they could oblige ISPs to include in their contracts mandatory clauses allowing users to share their connection. Another possibility would be to consider clauses that limit not-for-profit interconnection as void[83].

Such policies would reveal very valuable especially after the recent decision of the CJEU in the *Mc Fadden v. Sony* case[84]. In other words, policymakers should start giving importance to CNs and other similar projects, to promote their wellbeing and their diffusion. Scholars, on their part, have the task to bring to the attention of lawmakers the positive effects of CNs and the importance of their survival.

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directive/#

82 To obtain more exposure in front of EU institutions and the like, CNs should improve their ability to lobby. This is one of the tasks of the project netCommons.eu, of which I am part.

83 I wish to thank the anonymous reviewer for this suggestion.

84 C-484/14, Tobias Mc Fadden v. Sony Music Entertainment Germany GmbH, cit.

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Part II
Do It Yourself: Creating Connectivity Around the World

6. A Network by the Community and for the Community

Ritu Srivastava

Abstract

The expression "Digital Divide" or "Digital Information Barrier" refers to the substantial asymmetry in the distribution and effective use of information and communication resources. It is widely believed that the global information highway, by opening two-way information flows, empowers individuals and communities, particularly creating new opportunities for individuals living in remote areas. This is possible if connectivity is provided to them, in order to access wide range of markets, seek new opportunities, learn new skill sets, get better quality health care, become aware of their rights and exercise them. Mobile phones and cellular technology enable people to connect with other like minded people and groups, Internet has become an integral part of economic, social and cultural lives, shaping the way we communicate with others, bringing education in our home, creating new jobs, raising their voices and opinions, sharing and receiving information. The content of the Internet is continuously widening, covering more aspect of social and political life, which in itself has a great democratising effect. Poor access to the internet, however, is currently denying such opportunities for people who do not or merely have access to the Internet. However, empowerment become possible when people are able to build their own networks and have enough capacity to manage those networks.

"Wireless Community Networks" or Community based Internet Service Provider (C-ISP) are such networks whose infrastructure is developed and built by small organisations and community members by pooling their resources. These networks are managed, operated and owned by com-

munity members. These networks offer affordable access to the Internet while building community and strengthening the local economy (Centre for Neighbourhood Technology, 2006). These networks are meant to provide the last mile access not only at village council level but also at household level. To provide the last mile access, the government of India has proposed various action plans including the National Optic Fibre Network (NOFN)[85] under its umbrella vision, Digital India explained later on this paper. The challenge is not only limited to laying wired infrastructure but also how to connect the country with availability of limited bandwidth. This implies a need of a decentralised model to highlight the existence of various patterns of using ICTs and alternative solutions to foster sustainable connectivity and create sustainable smart villages.

India based organisation, Digital Empowerment Foundation (DEF)'s wireless for communities programme is one of the community wireless networks that is trying to provide affordable, ubiquitous and democratically controlled Internet access in rural regions of the country. The network enables for community economic development that can reduce poverty and encourage civic participation. This paper explores DEF's wireless for community programme as a case-study of creating viable smart villages in the country by engaging communities The paper seeks to set up model of superset of Internet points that is localised to meet specific needs of communities. This paper investigates the efficacy of creating wireless community networks (WCN), Rural Internet Service Provider (RISP) or Community-based Internet Service Provider (C-ISP), and explores the possibility of policies, which could help in creating widespread information infrastructure for the larger masses of the country.

6.1 Introduction

The emergence of a global 'information society' is driven by the continuing development of converging technologies of telecommunications, multi-media broadcasting and information technology. In just a few years, the Internet has undoubtedly turned into one of the most dynamic communication tools the world has ever seen. The flow of information that it facilitates strengthens democratic processes, stimulates economic growth and allows for cross-fertilising exchanges of knowledge and creativity in a way never seen before.

Since the time this powerful tool of development was first introduced, the Internet has undergone profound changes. The Internet has become a

85 National Fibre Optic Network (NOFN); http://www.bbnl.nic.in/index1.aspx?lsid=249&lev=2&lid=21&langid=1

key instrument for social, political and economic activities in developed countries and, as broadband penetration increases, will arguably become so also in developing nations. This implies a strong dependency on both the basic infrastructure of the Internet and the applications that run on the internet.

According to the ITU report, 3.9 billion people (about 53 per cent of the world population) are not using the internet by the end of 2016. Similarly, in Asia and the Pacific and the Arab States, the percentage of the population that is not using the Internet is very similar: 58.1 and 58.4%, respectively[86]. The disproportion in the access to ICT infrastructure and availability, accessibility of the technology at hand, digital literacy, availability of relevant content and limited availability of telecom operators in rural regions lead to unequal access to the internet. It is therefore, vital that the resilience and stability of this global network of networks is ensured. This seems to be especially in the case of rural areas and informal sector where people are more likely doing odd jobs are isolated and deprived (Essellar *et al* 2007).

The Millennium Development Goals (MDGs), set out in 2000 as part of the Millennium Declaration, have been updated by the MDGs as part of the Sustainable Development Goals (SDGs) in September 2015. The Goal 8 Access to New Technologies, established by the United Nations in 2000, was created to promote the adoption of broadband-friendly practices and policies to spread the benefits broadband Internet can offer and to ensure the broadband Internet technologies accelerate progress towards meeting MDGs (UN Millennium Development Report).

The United Nations Task Force on Innovation, Science and Technology in 2005 defined that the growing gap between the haves and have-nots may fundamentally threaten the possibility of achieving the MDGs. According to the Task Force,

"… the gap between people with access to local and global networks and people without such access is widening. Narrowing this gap represents an enormous challenge. The means to meet this challenge are already within reach; failure to urgently and meaningfully exploit them may consign many developing countries, particularly least developed countries, to harmful and possibly permanent exclusion from the network revolution. Within the development community, there is growing awareness that failure to include developing countries in the ICT revolution will have serious consequences for achievement of the goals. Harnessing the strategic and innovative use of ICT in development policies and programmes may enable the world to meet the goals. Without such technology, doing so by 2015 will be impossible." (Juma and Yee-Cheong 2005, p. 50).

86 ITU Report, Facts and Figures 2016; https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf

Poor access to the Internet, however, is presently denying the benefits of the information age to underserved people in a variety of developing countries such as India and many other South Asian countries. Although India is the third largest nation of Internet users by absolute numbers, Internet penetration in the country, at 19.19 per cent, is still below the 40 per cent global average. It is the same situation in other South Asian countries such as Bhutan, where Internet penetration remains low at 27.7 per cent, Sri Lanka (19.9 per cent), Nepal (12.3 per cent), Pakistan (10.84 per cent), and Bangladesh (6.9 per cent).

The key hurdle in increasing Internet penetration in rural areas lies in so-called "last mile" connectivity. The huge costs associated with rolling out wired infrastructure, in addition to the lack of commercial viability in localities with a low user base, have in many instances deterred governments and the private sector from prioritizing rural connectivity in many parts of the region (Noll 2000). Leased line cost and international connectivity are two key components that increase the internet access price. In many cases, regulation discourages competition in the provision of backhaul services and last-mile connectivity (Wallsten 2003). Lastly, in most rural areas low population density and high deployment cost discourage private investments that further create a negative feedback of limited capacity, high price and low service demand (Sarrocco 2002).

Over the past decades, however, technological progress in key areas of wireless communication and cost reduction in core equipment components have fundamentally changed the cost equation in favour of wireless solutions, particularly where wired infrastructure does not exist.

The evolution of networks in developing countries is taking an alternate route from the traditional networks. In developing countries, wireless connectivity has emerged as one of the inexpensive technologies to bridge the connectivity gap in remote areas. Like other technologies, wireless technologies like microwave, WiMax, Wi-Fi-based networks require much lower capital investment than laying down optic fibre. The technology was initially conceived for shirt-range connections between computers within homes and offices (cordless Ethernet), however; soon it became clear that it could also be extended to use into public spaces. Since 1997, Wi-Fi technology has experienced an extraordinary growth when the IEEE finalised the original 802.11 specifications[87]. It is estimated that there are

87 4. Today, Wi-Fi comes in three basic ºavors: 802.11b, which operates in the 2.4 GHz frequency range and offers speeds up to 11 Mb/s; 802.11a, which operates in the 5 GHz frequency range and offers speeds up to 54 Mb/s; and the most recent 802.11g, which is backward-compatible with 802.11b but offers speeds up to 54 Mb/s. Work continues on variations that will improve the range, security, and functionality of Wi-Fi.

12 billion wi-fi enabled devices worldwide[88]. There are various factors that explain the success of Wi-Fi -

1. Wi-Fi can deliver high bandwidth without the wiring cost, which makes effective replacement for last-mile internet access as well as backhaul traffic where installation and maintenance cost of wired infrastructure are prohibitive

2. There is widespread industry support for the Wi-Fi standard, co-ordinated through the Wi-Fi Alliance, an industry organisation including over 200 equipment makers worldwide[89]. Thus, the cost of Wi-Fi equipment has been dropped rapidly; therefore, users can expect compatibility between Wi-Fi client devices and access points made by different vendors.

3. Wi-Fi networks works on unlicensed bands, namely thin slices of radio spectrum that is reserved for low-power applications in which radio devices can operate on a license-exempt basis.

One of the major factors is that WLAN technologies enable the delivery of broadband services even when the local telecom infrastructure is scarce or unreliable. Network deployment cost is considerably lower since WLAN technologies require minimal wiring expenses, which can compromise up to three quarters of the upfront cost of building traditional telecom networks (Caspary and O'Connor 2003). Instead of using poles and wires, WLAN technology take the advantage of natural resources, which are typically under utilized in rural areas and radio spectrum. Low-cost access systems based on Wi-Fi technology have already been deployed to service rural villages in Southeast Asia at a cost two orders of magnitude below that of comparable wired solutions (Best 2003; Pentland et al. 2004). This allows for a new type of decentralized rapid evolution of such networks, driven by local communities and entrepreneurs.

This paper brings examples of community-led wireless networks that are connecting the communities living in remote and difficult geographical environments. Particularly, the paper examines various existing and viable community wireless network models that are providing low-cost Internet connectivity in rural locations across diverse communities spread over several states of India.

88 Wi-Fi Alliance; http://www.wi-fi.org/news-events/newsroom/wi-fi-device-shipments-to-surpass-15-billion-by-end-of-2016

89 5. The Wi-Fi Alliance was formed in 1999 to certify interoperability of various WLAN products based on the IEEE 802.11 specifications. Since the beginning of its certification program in 2000, the group has certified over 1,000 products.

6.2 Internet and its impact

Internet has greatly influenced the way individuals socialise, create and exploit economic opportunities and knowledge resources. Few studies have measured impact of Internet in an integrated manner – examined the aspects of social, economic and knowledge enhancements that further helps in understanding the phenomena constituting the impact of internet use. Past studies have measured these impacts with two theoretical and complementary domains: social capital and social cognitive theory. Social Capital refers to the network of near and distant social ties that individual draw upon enhancing their information base, knowledge, influence, solidarity for economic or other benefits such as improving professional status (Adler and Kwon, 2002, Coleman, 1988; Dekker and Uslaner, 2001; Dolfsma and Dannreuther, 2003; Putnam, 1995; Putnam, 2000). These networks provide the underlying mechanism for individuals to enhance their knowledge and provide an environment for knowledge exchange (Lane and Lubatkin, 1998; Snowden, 1998; Wellman and Wortley, 1990).

Since the internet is considered as a network of social exchanges, thus, it is important to take social capital consequent and internet usage into account. On other hand, usage of internet can lead to increase in economic capital due to enhanced opportunities for businesses or profession. Social capital can also lead to increase in knowledge that could further enhance economic or social status.

Putnam (2000) defines "Social Capital" as a set of horizontal associations among community members for leveraging their existing resources embedded in the network. Social Capital is considered as an inherent part of the social network and the relationships that constitute the network Coleman (1988, 1990). According to (Lin, 2001; Helliwell and Putnam, 1995; Knack and Keefer, 1997; Temple, 2001) Social Capital has the potential to provide growth, productivity, equality and pecuniary gains. While Yang (2007) defines Social Capital as a collective property, where individuals can draw personal benefits at different levels through the social groups or networks that each individual member can access and hence Social Capital can be measured at the individual level too. Nahapiet & Ghoshal (1997) considered Social Capital as i) structural that consist of the ties and relationships embedded in the network; ii) relational consisting of factors such as trust and motivation; iii) cognitive consist of shared vision, motivation.

According to (Beugelsdijk and Smulders, 2003; Lancee, 2010; Leonard, 2004; Ryan, 2011) "Structural Capital" udefully bridges networks, creating economic capital by supporting employment and enhancing income. Structural Capital components usually refer to the interaction between actors. As interactions with others allow individuals to leverage their social characteristics, Social Capital may be linked to Economic Capital (Glaeser, et al, 2002).

Social Capital can be converted to other kinds of capital as the social network may be leveraged for economic gains and knowledge enhancements (Adler and Kwon, 2002). On other hand, both knowledge and economic capital could lead to development or enhancement of Social Capital. Increased productivity and innovation, value chain re-composition, access to public services and information, reduction in transport time, timely access to education and health services are major economic impact of internet. It has enabled growth in scope of earning and include behavioural changes with respect to new ways of earning more by increasing scope of doing business, increasing customer/subscriber base, enhancing product portfolio, enhancing employment opportunities. Social Capital is associated with job prospects, career compensation and resource exchange (Hsu and Hung, 2013).

6.3 Connectivity & Internet Access Infrastructure

Former Indian President, Dr. Abdul Kalam coined the concept of PURA (Providing Urban Amenities in Rural Area) to foster the social economic system for sustainable growth. PURA stands for a well-planned drive towards achieving an inclusive and integrated development starting at village household level and evolving village community level (PURA: Ministry of Rural Development Annual Report 2010).

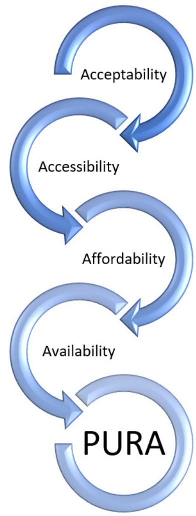
Notably, PURA involves the National e-Governance Plan (NeGP)[90], formulated by the Department of Electronics and Information Technology (DEITY)[91] and the Department of Administrative Reforms and Public Grievances (DARPG) , which has devised 27 Mission Mode Projects (MMPs)[92] to make the government service accessible and affordable for citizens.

The Plan argues that Internet usage in rural India can be spurred by focusing on the critical factors of 4As – Availability, Affordability, Accessibility and Acceptability. First time, PURA envisages an integrated development plan with employment generation as the focus, driven by provision of the habitat, healthcare, education, skill development, physical and electronic connectivity and marketing.

90 National e-Governance Plan (NeGP); https://negp.gov.in.

91 Department of Administrative Reforms and Public Grievances (DARPG) http://darpg.nic.in.

92 Mission Mode Projects; http://meity.gov.in/content/mission-mode-projects.



The UN Broadband Commission defines broadband as affordable if an entry-level 500 MB data plan is available at 5 per cent or less of average monthly income (i.e., GNI per capita)[93]. The problem with this definition is that with the reality of high-income inequality in many of the countries that have achieved the 5 per cent of the target, the entry-level broadband – 500 MB is still too expensive for at least the bottom of 20 per cent income earners and often remains out of reach for all those except the top group of income earners. The affordability is measured against the cost of 500 MB data plan, however, the reality is that users need more data and meaningful use of the web. According to the UN, over 75 per cent of developing country households live in societies where income is more unequally distributed than it was in 1990s. When a few people earn a lot while others earn very little, the "average" per capita income – the benchmark the UN uses to assess affordability – will be much higher than what most people actually earn. According to the Internet World Stats (2014), the percentage of people who do not have affordable high-speed Internet is 84% in Africa; 78% in Asia, 37% in Europe; and 22% in North America.

These people are lagging behind, in the digital sense, because they are not part of the information society. Such communities usually lack viable commercial incentives to attract telecommunication companies.

93 Broadband Commission; http://www.broadbandcommission.org/Documents/Broadband_Targets.pdf.

Wireless technologies have shown much potential to provide high-speed Internet access to any community in any location either through terrestrial telecommunication infrastructure or satellite backbones (Abdelal and Al-Hinai 2014). WLAN technologies create an alternative to the top-down network deployment model associated with traditional telecom infrastructure, an alternative to extend internet connectivity in rural regions of the developing countries. Cost advantage associated with wireless, the use of unlicensed spectrum makes easy for local actors to use the wireless technology easily. A flexible infrastructure can therefore expand the bottom-up approach, without having any pre-conceived plan and links to the needs and attributes – geographical, demographic, economic of local communities (Best and Maclay 2002). Thus, wireless networks are relatively easy and quick to deploy, particularly in cases where towers are not required.

The deregulation of the 2.4 GHz and 5.8 GHz spectrum-bands[94] has also given opportunities to non-profit organisations and small Internet stakeholders to build their own wireless networks using Wi-Fi standards and avoiding dependence on a telecom carrier. This kind of low-cost connectivity is important for rural areas, which are less enticing to carriers due to low density and income of potential consumers.

6.4 Wireless Community Network and Infrastructure

Wireless community networks (WCN), also known as bottom-up networking, is an emerging model for the 'Future of Internet' where communities are able to deploy, manage and operate their own networks. These networks are part of the Internet but present various "exceptional" features such as low cost and effective, public documentation on every technical and non-technical aspect; they operate and own open IP-based networks; they are built by communities of individuals, and are based on collective digital participation.

Technically, these community networks are large-scale, distributed and decentralised systems comprising nodes, links, content and services. The networks are dynamic, diverse and governed by open peering agreement that avoids barriers for the participation in the network. Governance, knowledge and ownership of the network are open. Therefore, these networks are not only decentralised but also self-owned and self-managed by community members, capacity building and various services are provided

94 http://cis-india.org/telecom/unlicensed-spectrum-brief.pdf

by community members. Most of these wireless community networks are often built with simple, low cost and shelf hardware.

These nodes are usually running an open source distribution such as Linux (Openwrt) or FreeBSD. Therefore, the process of planning the infrastructure and designing the network differs significantly, depending on whether the networks are conceived by WCN, ISPs or other service providers. These key differences include the following requirements for planning WCN:

1. Ubiquitous Wi-Fi access covering the whole territory where the community is established (e.g. a city, a county or a province), no matter if some parts are sparsely populated and/or geographically challenged;
2. WCN not only provides internet access but also provides other forms of access, depending on the application and the users' needs and economic possibilities. Thus, on one hand, the services must be made accessible via cheap communication services such as 2.5G (GPRS), and, on the other hand, bandwidth-demanding customers have to be served too;
3. Mobility or at least nomadic access across the covered area must be supported;
4. Support of a multiplicity of user devices from simple mobile phones through PDAs and laptops to video conferencing equipment;

The network can provide various services not only limited to e-governance schemes; health, education but can be extended to community-based content and services.

6.4.1 Existing community wireless networks

In India, there are very few social enterprises working for designing or deploying wireless programmes to cater to communities. AirJaldi[95], in Dharamshala, and Digital Empowerment Foundation[96], in Delhi, are two organisations, which are providing basic connectivity and enabling access to information for citizens outside urban centres, particularly in rural and remote areas.

AirJaldi started as a social, non-profit enterprise established in Dharamshala, Himanchal Pradesh (HP) that provides affordable, wireless

95 Airjaldi; https://airjaldi.com.

96 Digital Empowerment Foundation; www.defindia.org.

broadband connectivity to remote rural areas at reasonable cost. It was born out of the efforts of a group of people who visited Dharamsala frequently and developed an affinity for the place and its people—mainly Tibetan refugees—and wanted to do something for its development. Yahel Ben-David, an Internet pioneer from Israel, and Michael Ginguld, an Israeli engineer with a masters from Harvard, founded AirJaldi. It was born out of a need for a network that connected local institutions and the community via the Internet. However, the infrastructure was not available.

AirJaldi provides community-based wireless mesh network in cooperation with the Tibetan Technology Centre in Dharamshala. The Mesh backbone includes over 30 nodes, all sharing a single radio channel. Broadband Internet services are provided to all mesh members. The total upstream Internet bandwidth available is 6 Mbps. There are over 2,000 computers connected to the Mesh, and about 500 have Internet access, the rest have intranet and connected locally.

AirJaldi led to a wireless mesh area network in and around Dharamsala which interconnects thousands of computers within a difficult mountain terrain, covering a radius of around 50 kilometres, and provides broadband Internet access, VOIP telephony, file sharing, offsite backup and video based application. By integrating multiple existing open-source software projects, with a little on-site tuning, the team managed to build one of Asia's largest wireless mesh networks. The network has exceptional affordability, performance and features, suitability for rural settings and communities, modular design enabling expansion in line with needs and demand.

Another example is of Delhi-based NGO Digital Empowerment Foundation (DEF). Its programme Wireless for Communities (W4C)[97] deploys line-of-sight wireless technology and low-cost Wi-Fi equipment, which utilise the unlicensed 2.4 GHz and 5.8 GHz spectrum bands, to create community-owned and community-operated wireless networks. The ideation behind the project was twofold: firstly to democratize the availability of connectivity and provide internet access to information in rural parts of the country, secondly to address the issue of lack of content product and services originating from rural areas which affects the economy from percolating to the bottom of the pyramid.

The programme has three main components:

a) Training the trainers for technological know how of wireless networking

97 Wireless for communities (W4C); www.wforc.in.

b) Deployment of wireless across rural communities, especially in clusters

c) An open forum to discuss best practices, lessons learn and to educate them on issues from both a technical and policy perspective

To further localise the initiative, the project strengthens grassroots expertise by training community members in basic wireless technology, enabling these 'barefoot engineers' not only to run and manage these networks but to pass on their skills to others. The programme also provides local content development and technology support to barefoot engineers.

Alongside each network, information hubs known as Community Information Resource Centres are set up to provide digital literacy training to women and youth members, to enable them to utilise Internet connectivity for their own needs. These centres also drive the W4C's developmental agenda, which can be summed up in a single word – AHEAD.

A - for awareness building on social rights and services through online avenues like social media, and on laws and issues such as the Right to Information Act and women empowerment;

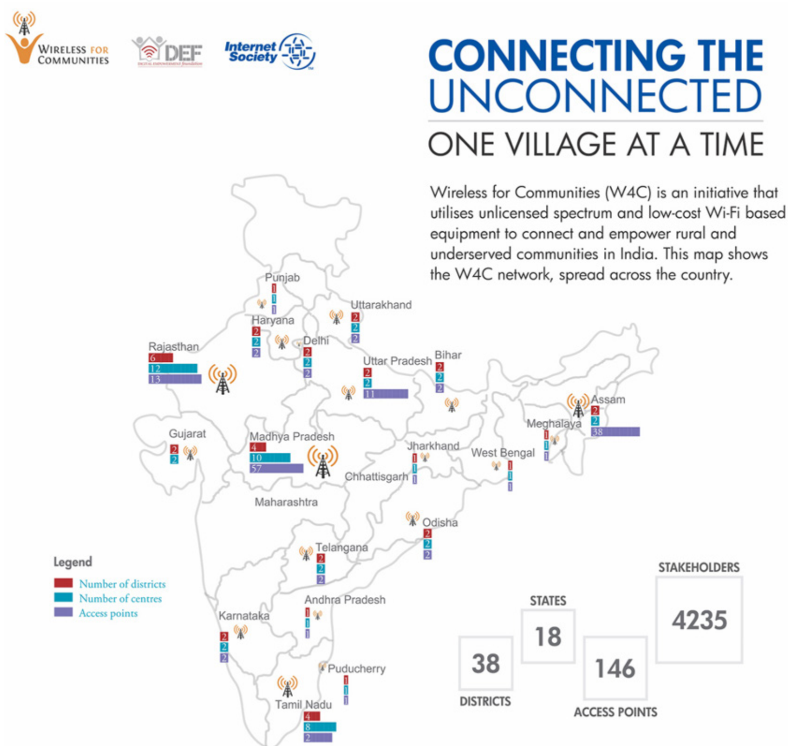
H - for health, such as telemedicine to connect primary health centres to district hospitals and enable local communities to access health-related information through the Internet;

E - for education for school dropouts, and access to online tutorials, distant learning courses, and online learning materials;

A - for activating entrepreneurship by enabling community members, particularly women, to set up e-Commerce sites and businesses that offer online services like e Ticketing;

D - for delivery of governance online, thus helping to facilitate greater coordination between local governments, expedite the delivery of public services and enhance state transparency and accountability

Over the past six years, DEF has provided connectivity in over 30 locations through 146 access points. These locations are Tilonia, Baran, Alwar and Chandauli (Rajasthan); Guna, Chanderi and Shivpuri in Madhya Pradesh; Giridih in Bihar; Aizwal, and Tura and Nangoan in the North East. It has succeeded in making more than 4,000 rural youth, children and women digitally literate. It has also provided telemedicine facilities to several communities that had no access to health care, linked together more than 50 panchayats, and connected 50 rural schools, several non-government organisations (NGOs) and a number of micro, small and medium enterprises to the Internet, thereby enhancing their operational efficiency and productivity



Baran has 1,235 villages represented by 214 panchayats. The district has a large population of Sahariyas – a highly exploited tribal community who reside mainly in the two blocks of Shahabad and Kishengunj.

The plight of the Sahariyas stems from big land owners in the area subjecting the tribal community to feudal practices such as bonded labour, taking advantage of their poor literacy and lack of awareness of their rights and entitlements. The district administration has yet to acknowledge the existence of bonded labourers in the district and local authorities have yet to take serious action against the abuse and atrocities being inflicted on the Sahariyas and other tribal people.

Following a famine which killed 47 Sahariya members in 2002, women in the village, with help from activists and local organisations, set up Jagrut Mahila Sangathan, which began to work on five major demands: (1) wheat at Rs 2 per kilogram as promised by the government; (2) right to work; (3) right to information; (4) inclusion of Kishenganj and Shahabad as Scheduled Areas (Adivasi areas) under the Panchayat Act of 1996 and; (5) recognition of the Kheruacommunity as a scheduled tribe. The group's demands were gradually met by the state, and in 2013 members of the Sahariya and Kherua communities in Baran were guaranteed 200 days of work, double the number of guaranteed work days elsewhere in the country.

The W4C programme has given a big boost to the activities of the Jagrut Mahila Sangathan. After the W4C project equipped seven Community Information Resource Centers (CIRC) with Internet connectivity, the Sangathan have been able to further increase their membership and immediately address the issues affecting women and bonded labourers. At the same time, it also allowed Sahariya and Kherua community members to easily voice their grievances and concerns without having to travel or take time off work. Cases are documented through video conferencing and forwarded to the block and district levels for remedial action. As a result, more than 35 bonded labourer households have been freed since 2010, and every year three to four new families come forward with evidence of abuse. More than 600 bighas of land have likewise been recovered from errant landlords.

Internet connectivity also aids the initiatives of Sankalp Samaj Seva Sanstha, a local NGO which set up the Dusra Dashak project to help school dropouts, especially girls, continue their education. Many students who underwent the four-month residential course in preparation for Class X and Class XII open school examinations found living away from their families difficult and tended to abandon their studies to go back home. These days, video conferencing allows them to communicate with their parents while completing the programme. Similar online facilities are used for e-health. The Bhanwargarh CIRC has a telemedicine kit that is connected to a health centre in Kota where specialist doctors of government hospitals provide consultation services to local patients. As well, community members who have received digital literacy training are becoming trainers themselves and operating new CIRCs.

6.5 Wireless Community Network & Entrepreneurship

The hub-and-spoke wireless network model has a long-term goal to maximise the benefits of wireless technology for the rural population in sustaining their lives. Thus, to maximize the efforts of wireless technology, it is important to use the technology in sustainable and viable models. These models could be public-enterprise models and to make the model long-term viable, the W4C programme has incorporated the following elements:

1. Usage of refurbished computer and other digital equipment
2. The first is oriented toward capacity building, where the community receives training on how to establish community wireless networks. Communities are empowered via a structured Training of Trainers programme that equips participants with the information they need to design, deploy, and operate wireless networks. This helps build a pool of local experts, who in turn can train community members. A separate workshop, held in qualified rural locations, introduces local community members to wireless networks and their deployment and operation.
3. The second component is the actual deployment of wireless network infrastructure in rural locations. The technology used is Wi-Fi, which is generally structured in a wireless mesh-type configuration for redundancy and reach, providing access in and around a community (usually a village).
4. The third entails broadening Internet access in existing locations by expanding Wi-Fi connectivity to surrounding areas. Community workshops to enable local Internet users to create content and services online are also carried out.
5. W4C networks are able to provide customised services according to user needs, thereby bringing down the cost of broadband services for rural users.
6. The project enables a large number of users, including local tribes, to use wireless infrastructure and facilities for self- and community-development. The ICT and vocational training provided to underserved communities is also helping many people to become entrepreneurs and improve their livelihood.

As defined in previous section, Internet and its usage have crucial social and economic value. Providing Internet services for various purposes from education, health, access to information, local market, employability to entertainment could be an avenue for making these models sustainable specifically in those areas which are unconnected due to geographical and demographical challenges. Most of these wireless for community networks are based on community needs, their demand and managed by them. These models are designed by community members and operated by them, thus they understand how to manage these wireless community networks. The project earn revenue in two ways: (a) By charging a small fee for providing connectivity to households, small institutes, NGOs, and small and micro businesses, and (b) As a community service centre, by charging customers a small fee for courses, Internet access and online services like e-ticketing and digital literacy programmes. The specific sustainable model is determined by customer need and local purchasing power. This helps to keep the network sustainable while providing customers the services they want at a fee they are willing to pay. Thus understanding the need of community is very important. In this perspective, this model fosters the provision of the following services:

1. Internet access

- Providing simple internet access service that is available to students, teachers, community members, and tourists
- Opening Email: Free accounts available through any web mail services to the villagers
- Telephone service: Villagers can place ordinary landline phone calls through Internet telephony equipment and the PBX software on the network server.

2. Education

- Increase opportunities in community schools by creating a live tele-teaching or virtual classroom programme for students
- Connect local schools with teachers for guest lectures
- Create online library for students
- Provide contents in local languages to students and villagers

3. Health

- Establish a tele-hospital in urban area and link it to district-level hospitals and rural health centres
- Provide medical assistances to villagers through a tele-medicine programme

4. Communication

- Increase communication facilities in the isolated rural areas by providing:
- VoIP phone
- Video conferencing facilities
- Bulletin board
- Internet services

5 Local e-Commerce

- Help villagers sell and buy their products in the local market and outside through local intranet and Internet

6. Jobs and business opportunities

- Generate jobs for younger generation locally through remittance services
- VoIP phone services for International calls
- Credit card transaction services for tourists
- Secretarial services (photo copy, photo print, document print)

7. 4 Cs Collaboration

- Cyber Café
- Community centre
- Cinema
- Classroom

Most of these services can be on charged basis as per rate card suggested by community members. Moreover, making these wireless community networks viable, the model uses:

i. Charging fees for providing community broadcasting services such as movies, documentaries, etc

ii. Charging minimal fee for providing internet related services and trainings

iii. Identifying local partners for collaboration and to further support the network

iv. Local e-commerce portal for community members to sell their products online

v. Generate jobs for younger generation locally through remittance services

6.6 Challenges

a. Bandwidth issues

1. Availability - High infrastructure costs, combined with a low customer base, constrain mainstream Internet service providers, or Class A ISPs, from extending their operations to remote or rural regions. In most areas the only backend bandwidth available is from the block-level SWAN set-up of state-owned telecom company Bharat Sanchar Nigam Limited (BSNL). The service quality is often poor, resulting in the wireless network suffering from periods of downtime.

2. Carriage - Several ISPs in urban areas provide bandwidth from their Base Transceiver Stations (BTSs) through a 20 to 30 metre Ethernet cable, yet they do not provide the required power (5 to 10 watts) for wireless equipment. They also do not share their towers for connecting user equipment and client devices.

3. Processing time - The process of obtaining a leased line from any ISP remains too time-consuming and overly arduous even after all required documents have been submitted. This is partly because of the further need for three-level coordination with all stakeholders who are providing the back-end bandwidth. This means that it takes at least three to four months to obtain the requested connection.

4. Cost - Taking broadband connection to the last mile level is four times higher than the cost of taking wireless connectivity to remotest region of the country.

b. Legal issues

1. Spectrum - Currently only two delicensed free bands, 2.4 GHz and 5.8 GHz, can be used by Wi-Fi community networks. The 2.4 GHz band has three non-overlapping channels which can to some extent connect with limited line of sight over short distances, but these tend to be fully utilised in urban areas, making it very difficult to get good signal quality due to data collision as a result of overlapping channels. More data can be carried using the 5.8 GHz frequency, but this needs clear line of sight.
2. Government permits - Towers which are higher than five metres require Standing Advisory Committee on Radio Frequency Allocation (SACFA) clearance, along with other permits from the Department of Telecommunications (DoT), the Airport Authority of India (AAI) and the Wireless Planning Authority (WPC). Each one entails a lot of time and expenses. These are in addition to fulfilling online applications and other technical requirements for setting up a tower. Use of any wireless equipment also requires approval from the Telecom Engineering Centre (TEC).
3. Out-of-date regulation - Telecom Regulatory Authority of India (TRAI) regulations stipulate that those without class A, B or C ISP licenses cannot sell bandwidth to clients. Hence, a rural ISP using free unlicensed spectrum has to either become a franchisee of a licensed ISP to charge downstream clients, or share the unlicensed free spectrum resource with communities at its own risk.

c. Infrastructure issues

1. Tower location - Finding an appropriate location for a tower to establish a point to point (PTP) link is often challenging as much of the land is owned by other entities, such as the government, or are not deemed suitable for infrastructure, in the case of forest land.
2. Power - With many villages lacking stable power supply, finding a power source at the required location remains a challenge-in several cases solar power was the only solution.

3. Protection from natural elements - Thunderstorms pose a major risk to wireless towers particularly during the rainy season. Consequently, extra equipment has to be maintained with system backup for network restoration should storms cause damage to them.
4. Device procurement - Spare parts for every device in the network have to be procured in advance and kept in stock as back-up should the primary equipment be stolen or damaged by natural calamities or by accident. This adds significantly to maintenance costs.

d. Human resource issues

Local expertise: In both urban and rural areas away from big cities, it can be difficult to find technically qualified individuals who can set up wireless networks. Those with basic computer literacy need additional training for them to learn how to set up, operate and maintain such a network.

6.7. Conclusion

The W4C project provides proof that using unlicensed free spectrum and low cost Wi-Fi equipment to set up wireless networks is a viable, cost-effective way to connect remote rural areas in India to the global information highway. Sustainability can be achieved by training local community members to become network enablers or 'barefoot engineers' who can operate and maintain such networks within the community. Connectivity, when combined with Wi-Fi-enabled information hubs, can help to empower communities and bring about holistic development.

The W4C model itself presents various business opportunities for Internet service provision. Rural ISPs that adopt it can become sustainable and commercially viable entities that offer Internet connectivity, digital literacy and other digital services at prices that the bottom of the pyramid consumers can afford.

The project has shown that there is a strong case for government to introduce a new policy for promoting rural ISPs which focus on serving underserved communities. It has also brought to the forefront some areas where existing policies need to be amended to ensure the spread of broadband connectivity in India.

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7. Map of the Community Network Initiatives in Africa

Carlos Rey-Moreno and Michael Graaf

Abstract

Community Networks (CNs), i.e. telecommunication infrastructure built by citizens for the benefit of their communities, have grown consistently and attracted considerable attention in recent years. In particular, there is a growing number of voices proposing them as a potential solution to provide affordable access in areas where the market is failing to do so. However, none of the many CNs, such as guifi.net, Rhizomatica or the Digital Empowerment Foundation, to name a few, come from Africa, where access to affordable communications is lacking in most places. This paper is an attempt to identify the reasons behind this gap by providing the first map of the CNs deployed in the African continent. CNs have been identified via web search and interviewing people directly or indirectly involved with their development. Results include the identification and profiling of 37 initiatives in 12 different countries, out of which 30 are currently at least partially active. Results show that 60% of these networks are located in one single country, South Africa, while only 1 (and not active anymore) was identified in the whole of Northern Africa. Additionally, in contrast with the common definition of CNs being large scale decentralized networks, in the African continent, most networks (82%) have less than 30 nodes, and have been either funded and/or bootstrapped externally. Only Wireless User Groups in South Africa follow the definition above. We believe that, bearing in mind the many particularities of different contexts, these results are a necessary first step to start understanding the CNs movement so they could have a greater impact in Africa.

7.1. Introduction

In recent years the community networks movement has grown consistently and attracted considerable attention from both funding [1] and academic bodies [2, 3]. The common understanding that the market forces are unable to provide affordable access to communications in remote areas [4] has led some to start advocating for community networks as the solution [5]. Countries such as South Africa have echoed this trend and incorporated them as part of their digital strategy in their National Broadband Plan [6].

However, the almost total majority of examples that are used to highlight the benefits of this model come either from Europe [7], and more recently from Latin America [8, 9] and Asia [10, 11, 12]. In the African continent, where the affordable access to communications is far from being a reality, very little is known about what is happening at the community networks space. Despite the efforts from some of the academics involved in these projects to disseminate their results in international venues [12, 13, 14], a map of the different initiatives and their current state is missing. Actually the Wikipedia entry for Community Networks in English was empty until one of the authors of this paper linked it to the entry about Community Networks in South Africa [15], which was itself outdated [16].

Identifying the different initiatives per country will allow an easier communication with the main actors involved in their development should other people want to engage with the movement in a specific location and get a sense of the challenges they may encounter. Additionally, it could serve as a point of departure for future studies about community networks in the continent to inform policy, donor strategies to fund similar initiatives and civil society organizations willing to replicate them.

This paper its a first attempt at filling this gap. In the next section the methodology to create this map is described. This is followed by the map itself, including the initiatives identified in each country and their current operational state. The final section includes the conclusion of this research exercise and the future works that will follow.

7.2. Methodology

The first author of this paper has been involved in different action research initiatives aiming at providing access in remote communities for more than ten years. This, together with an active engagement in two community networks in Southern Africa and the Village Telco community in the past

5 years has allowed a preliminary identification of the different initiatives and actors in the continent.

This has been complemented by a Google search in both English and French for the terms "community network", "community wireless network", "community mesh network", "wireless mesh network" and "Africa".

Additionally, the people identified in both steps have been contacted to get an updated picture of the community network they are involved with, to identify other community networks in the continent and to provide their views on the main opportunities and barriers around this type of initiatives. Due to lack of space the latter could not be included in this paper. In total 60 people/entities were contacted, of which 35 answered the request (although sometimes only partially). Additionally, the request was sent to 5 mailing lists with potential knowledge on the topic.

Profiles of each community network identified has been sent back to the main people involved in each of them for confirmation. We would like to apologize in advance to any community network that has not surfaced in the process described above and so, not included here.

7.3. Map of the Community Networks in Africa

Democratic Republic of Congo

Mesh Bukavu [17]:

This network is a project of News for Peace, which among other things runs Radio Maendeleo, a community radio station. It is the result of a collaboration of Free Press, a Dutch organization, and was bootstrapped with funding and training from the Open Technology Institute (OTI). The training took place in November 2014 and the network was deployed in January 2015. It has a strong emphasis on local hosting of content (Wikipedia, blogs, audio lessons, e-books), and also other local services like a local chat. It is valued also as a standby when official net shutdowns occur, e.g. at election times.

The network, which is still operational, consists of 10-15 nodes, (Ubiquiti NanoStation and Rockets) running Commotion firmware. Equipment is mounted on rooftops of participant organisations especially if they have backup electricity (solar is being phased in).

Mesh Goma [17]:

Mesh Goma was initiated as an experiment of a local organization, the Collective of Community Radio and TV in North Kivu (CORACON), in partnership with Free Press Unlimited and inspired by Mesh Bukavu. It also received Seed funding from the OTI.

The network was initially deployed in January 2015 with the idea of providing access to information to the areas in the city of Goma which lacked this access. It consisted of 15 nodes (14 Ubiquiti and 1 Tp-Link). It is no longer operational due to the problems with access and costs of reliable electricity in Goma, and the lack of digital stewards keen to work voluntarily in maintaining the network. Additionally, the network was only providing intranet services, which did not make it attractive to the majority of the population in Goma.

Pamoja Net [18]:

Pamoja Net (pamoja means 'together' in Swahili) is a local mesh on the island of Idjwi in Lake Kivu, between the DRC and Rwanda. It reports 200 regular WiFi users, as well as institutions such as a radio station, the police, and the electoral commission. It also has a public display screen and tablets for casual users in a kiosk. Interestingly its backhaul is via line-of-sight links to Bukavu, where another community network is located (although Pamoja's gateway is via an internet cafe there).

The network was created in 2015 by Project First Light, a partnership of NGOs and businesses. The partnership still oversees operations, although it has trained local "guardians" to conduct day-to-day running. In terms of governance, the local traditional leader (who originally requested internet connectivity) is committed to operating Pamoja as a commons.

Ghana

Akwapim Community Wireless Network [19]:

This is located in Eastern Ghana and was installed and maintained by a small group of volunteers associated with the Apirede Community Resource center. Both the resource centre and the community network are projects of the Community-Based Libraries and Information Technology (CBLit), a non-government organization based in both Ghana and the United States. It started in 2005 in response to the local community's requests for connectivity to help them break their isolation, as an extension of a public library initiative, with the support of the US Peace Corps. Its first phase had 10 nodes, and the second was to have another 10. The second phase was also to use a V-Sat link. Most nodes use old PCs as routers, with new WiFi cards (Dell OptiPlex units and D-Link DWLG520 cards). Within this research, it was impossible to determine the current status of the network. However, its website is down and no information after 2009 can be found online, which lead us to believe is no longer active.

Kenya

Tunapandanet [20]:

This was started and funded in the last 5 years by an educational-development NGO (Tunapanda Institute, which got early funding via Indiegogo, and had high input from American "backpacker" volunteers). Network serves to further its outreach (educational activities centre on Edubuntu thin client system) into large, high-density slum. Of particular interest is the organisation's emphasis on cached/recorded content to avoid external data costs. Base station and 3 nodes: Ubiquity PicoStation (short range, omnidirectional), Ubiquiti NanoStation (medium range, directional), Ubiquiti Rocket. Network likely expanding as organisation is active.

Namibia

Connecting Eenhana [17]:

This was created in 2015 by partnership between the University of Namibia and the Glowdom Educational Foundation with a grant from the OTI to support learning amongst community members of the small town of Eenhana and surrounding villages . In particular it aimed at supporting the generation and sharing of local content and to increase access of schools to educational content, including for learners and students at a Special school for Deaf learners. Additionally, the local content creation was extended to provide local government information, as well as transparency and accountability of local government.

It connects 7 sites using Ubiquiti routers and Mesh Potato devices which also provide VOIP services. All the network runs SECN firmware. It is only partly functional at the moment, due to equipment failure due to overheating and difficult terrain (very flat and with tall trees, which prevent Line of Sight between the nodes).

Nigeria

Fantsuam Foundation [17]:

Started in 2009 with SEED funding and having only 2 nodes, ZittNet is a department of Fantsuam Foundation (an NGO in Kaduna State), and focuses mainly on ICT training and Last Mile Connectivity; nonetheless it was honoured as Nigeria's first rural ISP. It was also intended to provide rural students with access to (downloaded) offline study materials. It started off having a VSat connection but due to cost is trying to replace this with a fibre connection. It notably uses solar backup to maintain service in the absence of reliable grid power.

Ibadan WUG [21]:

Started by one of the Mesh Potato project's earlier contributors in a residential precinct in Ibadan. It is still actively providing connectivity largely to home owners and students. It consists of 22 Mesh Potatoes.

Somalia

Abaarso [22]:

Initiated by an American working as ICT instructor in Somalia to serve the Abaarso School of Science and Technology due to poor and at times non-existent internet. Also involved some local cloud hosting. Used Ubiquity & Commotion. Current status unknown.

South Africa

Siyakhula Living Labs [22]:

It started in 2005 project involving the Telkom Centre of Excellence at two universities, Rhodes and Fort Hare. The first network was intended to provide exposure to international markets to the local arts and craft entrepreneurs within the Dwesa community; and started off with 3 nodes at schools, consisting of WiMAX backbone with WIFI hotspots around each node, and a VSAT backhaul and later growing to at least 14 nodes. From the initial offering of e-commerce services this grew to providing information and communication services (including telephony services, emailing, school administration, etc.) both for the schools and the surrounding communities. The network grew from the three nodes to about 14+ (might have actually been 17 schools at the end) and offering a whole plethora of services to the schools and the communities. The network is still operational but barely, largely due to funding challenge.

The second network was started by a researcher from the University of Fort Hare (UFH) who deployed a community wireless mesh network consisting of seven nodes using nanostations m2 (3) and picostations m2-hp (4) connected through a VSAT sponsored by Sifunda Kunye Educational Foundation in a location called Ntselamanzi, Alice, Eastern Cape. Its operation is linked to a research project by a student at UFH, which meant that its active management and administration has slowed down since the student completed his work. Still, it has plans to be extended to neighbouring communities.

Rural Telehealth [24]:

The University of Western Cape led a series of rural wireless projects, lasting several years each, between 2003-2012, connecting remote hospitals and clinics in the Eastern Cape province. There was also an initial try at rural community networks, even mesh. These involved long range (up to 15km) line-of-sight WiFi links, in both 2.4 and 5GHz. At times, they were connected to one or two expensive VSAT links. All were powered by deep cycle 12v batteries, charged either by solar panels or trickle charged from unreliable mains. Despite robust technical performance, the networks and apps created for them were not fully utilised mainly due to social reasons, e.g. power relations, suspicion of our motivation and the single champion problem.

Peebles Valley Mesh Network [12]:

This mesh network in Peebles Valley, Mpumalanga consisted of 6 nodes and provided connectivity (Internet, local Wikipedia content and local free VoIP) to homes, farms, a school and other clinic infrastructure. The Internet link was provided by spare capacity on a VSAT link at an AIDS clinic in the area. The project was supported by an IDRC funded project called First Mile First Inch that included Meraka and various academic institutions and NGOs across Africa. The project lapsed due to the high cost of VSAT, legal uncertainty around community-built wireless networks and lack of continued support.

Bo-Kaap [25]:

A now-defunct "testbed" experiment in a historic inner-city precinct involving 75 of the early Mesh Potatoes and an internet gateway, funded by the Shuttleworth Foundation. The network was intended to test the capabilities of and debug evolving mesh WiFi voice technology in a live environment. Technology development challenges and a failure to build community ownership in from the beginning led to the project lapsing.

Orange Farm [26]:

Another pilot project in the development of the Village Telco technology/ business model, in a township near Johannesburg. Social enterprise Dabba installed Mesh Potatoes and cheap VoIP handsets. However the network seems to have lapsed after the rapid proliferation of cellular telephony created a more powerful "network effect" so the micro-entrepreneurs Dabba anticipated were not forthcoming.

Kranshoek Mesh, South Africa [27]:

A truly community-driven network in a historic coastal village occupied by an ethnic minority. Using Mesh Potatoes, it promised to bring relief from high communications cost in a context of high unemployment, but current status is unknown.

Zenzeleni Networks [14]:

Formed with technical assistance from the University of the Western Cape, it is registered as a co-operative and an Internet Service Provider, operated and managed by members of Mankosi, a rural community in one of the most disadvantaged areas of South Africa. It has 12 nodes linked to a 3G gateway. Each node consists of a Mesh Potato connected to a solar power supply. It provides access to voice services at a fraction of the cost offered by incumbent operators. Currently under way are the provision of WiFi hotspots and connection of local schools' computer labs, as well as backhaul improvement.

Scarborough Wireless User Group [28]:

A middle-class peri-urban DIY community was sharing internet access by mesh with each other and some poorer neighbours near Cape Town, S. Africa. At its peak it had about 200 nodes. Used Linksys WRT54GL, Ubiquity Nanostations and Mesh Potato V1's routers. Defunct due to arrival of cheaper, faster ADSL & fibre.

SoWUG [29]:

Hybrid CN/ISP in Soweto, South Africa. Started in 2010 with corporate sponsorship and technical support from the Johannesburg Area WUG. It provides WiFi hotspots in public spaces in Soweto and nearby peri-urban areas. The organisation's website maps out several operations it intends to expand into such as educational support.

Cape Town WUG [30]:

Although using the term "mesh" this large urban network (registered as a nonprofit organisation) is more correctly described as decentralised. With some hundreds of members, its only official connection to the internet is for POP email; otherwise, the main functions are offline file-sharing and gaming. It has a progressive constitution regarding sharing of skills and resources and some cross-subsidisation is evident between richer and poorer areas.

Johannesburg Area WUG [31]:

Similar to above; interestingly, is a member not only of Wireless Application Providers Association, but Internet Service Providers Association.

Durban Wireless Community (DWC) [32]:

Smaller (approx 50 nodes) and more sporadically active; founded 2004 and recently revived; a non-profit promoting wireless technology and computer networks.

Other WUGs [33]:

Another five nuclei of smaller, sporadic groups.

Pretoria Mesh [34]:

This is an experimental project started in 2006 in the suburbs next to the CSIR, to test hardware and software deployed in other projects throughout the country. It has about 20 nodes and is still active.

BB4All / Broadband-for-All [35]:

This is an abbreviation of Broadband Community Wireless Mesh Network which was a government sponsored research and demonstration program targeting the digital divide in rural areas. The implementation, launched in 2009 in Mpumalanga and Limpopo was transferred in 2014 to a commercial organisation providing school connectivity and public hotspots [36].

ICT4RED [37]:

The ICT for Rural Education (ICT4RED) project (2012-2016), undertaken by CSIR Meraka, was the largest research, development, innovation and implementation project of its kind in South Africa. It formed the ICT aspect of the larger Cofimvaba Technology for Rural Education Development (TECH4RED) project, a joint initiative between the Department of Science and Technology, the Department of Basic Education and the Eastern Cape Department of Education. TECH4RED is aimed at contributing to the improvement of rural education through technology-led innovation. ICT4RED was particularly successful in implementing technology in schools and in empowering rural teachers to comfortably use tablets in their day-to-day teaching activities, by using gamification principles and an "earn-as-you-learn" approach. ICT4RED employed a mesh network connecting 26 schools, with internet connectivity provided via shared satellite infrastructure. In 2016 the project has been handed over to the district and the province authorities to institutionalize the initiative

Home of Compassion [38]:

Home of Compassion, an NPO based in Delft (Cape Town), has piloted a community network since 2015.It started with funding from the Western Cape Government and the support of an external ISP to roll out the network but once they built enough technical capacity, they decided to become an ISP themselves. By November 2015, it had 20 active access point and 17,150 active devices. They offer 50MB allowance a day per device and once users reach their cap, they sell prepaid top-up vouchers though a network of local resellers. In addition to the provision of Wi-Fi connectivity, Home of Compassion provides IT training and through its network it is able to set up “call centres on-demand”. Finally, Home of Compassion has developed an app, which is zero-rated across its network, to purchase goods and services within the community.

Tanzania

The ICT for Rural Development Project (ICT4RD) [39]:

This nationwide initiative had 2 pilot networks set up in Bunda and Serengeti in 2006. Assistance came from Swedish researchers and the agency SIDA. Both pilots were motivated by existence of fibre optic cables owned by other entities, however use was also made of a VSat connection at Bunda. Local governments were involved to create ownership and sustainability but contributed to the demise of the first. The remaining one connects schools and hospitals.

Sengerema Wireless Community network:

A project of the Sengerema multi-purpose Telecenter which provides computer services, printing, office, internet, education, FM Radio Station (reaching 400 000 people) with support from Dutch NGO, IICD. In 2012 it had an internet connection - VSAT 128/64 kbps through COSTECH (Tanzania Commission for Science and Technology). The network served a large number of civil society and official organisations including schools.

It featured wireless routers: Linksys WRT54GL; firmware OpenWRT/Freifunk; self-built antennas (with some exceptions) and locally built masts. Current status unknown, believed to be lapsed.

Tunisia

Mesh SAYADA [40]:

A project of Clibre (a local open-web advocacy group) that started in 2012. The networking equipment (12 nodes) was donated by the Open Technology Institute, and the time was volunteer. The network is not really operating currently, largely due to the unstable sociopolitical situation.

Uganda

Bosco Network [41]:

Battery Operated System for Community Outreach (BOSCO)-Uganda is a Non-Profit Organization (NGO) under the trusteeship of the Archdiocese of Gulu. Funded and operational since the year 2007 the organization started in installing wireless Internet and VoIP telephony in internally displaced persons (IDP) camps with reliable eco-friendly energy. 9 years later BOSCO-Uganda is managing 32 Information and Communication Technology (ICT) Centers situated in rural communities and former internally displaced persons camps, consist of low-power, solar powered PCs connected to a high-speed, long-range WiFi Internet connection. Each communication station is linked to other BOSCO sites via a free VoIP telephony network and through a high-speed internal network (INTRANET) content management page that are all powered by solar energy and enabling thousands of Ugandans in acquiring ICT and entrepreneurship knowledge, connecting them with other communities (e.g. market platform) and the outside world.

Zambia

Macha Works [42]:

Macha Works' LinkNet internet provisioning in the rural community of Macha, in Choma District, Southern Zambia, is a renowned example of community networking in Southern Africa. The first internet connection became available for the community in early 2004, by means of a shared satellite internet connection with a medical research center in the community.

From its start, so-called 'local talent' gained experience in collaboration with international partners but always approached realities from the local perspective first. The networking morphs continuously, utilising a variety of available technologies. These (did) include mesh network technologies and direct WiFi links, the use of second-hand computers, and the deployment of locally refurbished sea containers for raising awareness of the internet in other rural communities in Zambia and Zimbabwe. With the implementation of a WiMax network by a commercial operator and with debilitating donor-led intrusions of the LinkNet developed 'market' in its community, Macha Works focuses more on user training, technical training, and the maintenance of ICT equipment.

The Macha network inspired and trained local leadership in both the technical and communal aspects of the provisioning of internet access in rural area. At least 7 other communities in Zambia emulate Macha's example and run a plethora of community networks and ICT services.

Zimbabwe

Murambinda Works [43]:

Established in the early 2000s, Murambinda Works at Buhera in Zimbabwe is focused on bridging the digital divice between rural and urban settings. In this sense, Murambinda works provides ICT training in rural communities where most schools lack relevant computer facilities. It is affiliated with Macha Works in Zambia and has various operations, including internet service provision and an internet cafe.

After using dial-up internet until 2015, it now has a fibre link to the national backbone. Training is provided for public officials including teachers, and any surplus revenue is channeled to a local foster home. Plans are afoot to extend to remote access points, perhaps even by satellite although for now costs are prohibitive.

Other initiatives related to community networks identified

The list below presents other projects identified in the search that either did not ever deploy a community network per se, or no data could be found to confirm that they were indeed deployed.

Comoros [44]:

This was to be an academic project funded from Qatar but its status is unknown.

Brubru, Kenya [45]:

The project seems to involve two brothers based in California (hence Bru-Bru). But a query to their contact page was not responded to in time to be incorporated to this article.

In the Wikipedia list of Community Wireless Networks in French [46], the following networks appear listed (for the first two no further information has been found online about them):

Agadir, Maroc Hotspot.ma, Dcheira, Casablanca

VIRTU@L CYBER, BUROCI Sarl - Abidjan, Cocody RCI

Cybervillage Africa, Cameroon [47]

This is not really a community network, but provides training workshops in wireless network construction, including solar power supplies. It aims at reducing the barrier for communities to deploy their own networks and bridge the digital divide. In 2016 they have provided several workshops across Cameroon.

Cotonou, Benin [48]

A Do it yourself project by a group of friends who wanted to bypass prohibitive prices.Additionally, two other initiatives had been identified where the infrastructure was created by mobile phones:

Mesh-Casting, Nigeria [49]:

Initially funded by Amnesty International and Internews, Rhizomatica, in conjunction with the Media for Justice Project, coordinated a mobile-mesh-based solution for a group of activists, citizen journalists and human rights monitors working in the Niger Delta region of Nigeria. The mesh part is no longer working, but the Media for Justice Project is still active.

Shika Moto, South Africa, [50]

An experiment by an NGO, Media Monitoring Africa, which was still in very early stages at the time of going to press.

7.4 Discussion and Conclusion

Information provided in the profiles above has been summarized in the Table and Figure below, for an easier visualization of the results.

Name	Country	Started	Active?	# of Nodes	Internet?	Location	Funding bootstra-pping
Mesh Buka-vu	DRC	2015	Yes	10 - 15	No	Urban	External
Pamoja Net	DRC	2015	Yes	6	Yes	Rural	External
Mesh Goma	DRC	2015	No	15	No	Urban	External
Akwapim Community Wireless Network	Ghana	2005	No	20	Yes	Rural	External
Tunapanda-Net	Kenya	2010	Yes	4	No	Urban	External
Connecting Eenhana	Namibia	2015	Partially	7	No	Urban	External
Fantsuam Community Wireless Network	Nigeria	2005	Yes	1	Yes	Rural	External
Ibadan WUG	Nigeria	?	Yes	22	Yes	Urban	Local
Abaarso	Somalia	2103	?	?	Yes	Urban	External
Siyakhula Living Labs – Dwesa--Cwebe	South Africa	2005	Partially	17	Yes	Rural	External
Siyakhula Living Labs - Ntsela-manzi	South Africa	2014	Partially	10	Yes	Urban	External
Rural Te-lehealth	South Africa	2003	No	7	Yes	Rural	External
Peebles Valley Mesh Network	South Africa	2005	No	6	Yes	Rural	External
Bo-Kaap Mesh	South Africa	2010	No	75	Yes	Urban	External
Orange Farm	South Africa	?	?	?	Yes	Urban	External
Kranshoek Mesh	South Africa	2011	Yes	30	Yes	Urban	Internal
Zenzeleni Networks	South Africa	2013	Yes	12	Yes	Rural	External
Scarborou-gh WUG	South Africa	2003	No	>200	Yes	Urban	Internal
SoWUG	South Africa	2010	Yes	29	Yes	Urban	External
Cape Town WUG	South Africa	?	Yes	>100	No	Urban	Local

Name	Country	Started	Active?	# of Nodes	Internet?	Location	Funding bootstrapping
Johannesburg WUG	South Africa	?	Yes	>100	No	Urban	Local
Durban Wireless Community	South Africa	2004	Yes	50	No	Urban	Local
BB4All	South Africa	2009	Yes	?	Yes	Rural	External
Pretoria Mesh	South Africa	2005	Yes	20	Yes	Urban	External
ICT4RED	South Africa	2012	Yes	12	Yes	Rural	External
Home of Compassion	South Africa	2015	Yes	20	Yes	Urban	External
The ICT for Rural Development Project	Tanzania	2006	Yes	?	Yes	Rural	External
Sengerema Wireless Community network	Tanzania	2008	No	17	Yes	Urban	External
Mesh Sayada	Tunisia	2013	No	12	No	Urban	External
BOSCO Uganda	Uganda	2007	Yes	43	Yes	Rural	External
Macha Works	Zambia	2006	Partially	99	Yes	Rural	External
Murambinda Works	Zimbabwe	2000	Yes	?	Yes	Rural	External

Table 1: Summary of Community Networks in Africa[98].

98 Note the smaller South African WUGs presented in Section 3 have not been included in this table for homogenization purposes

Community Networks in Africa

To our knowledge this is the first initiative producing a map of the Community Networks deployed in Africa. Results include the identification and profiling of 372 initiatives in 12 different countries, out of which 25 are currently at least partially active. Results show that 60% of these networks are located in one single country, South Africa, while only 1 (and not active anymore) was identified in the whole northern Africa. Provided that the authors are based in South Africa, results may show a bias in this respect. Still, it is would be worth exploring what other factors are behind these skewed results.

2 The 32 networks in Table 1 plus 5 small WUGs identified in South Africa.

It is the intention of the authors to use all this data with the contact information from each of the CNs that granted us permission to do so to update the existing Wikipedia article [15]. This would allow a dynamic update of the information presented here, including new CNs as well as those that have not been identified during this research.

In the interviews conducted it was surprising how little people involved in a CN know about other networks in the continent (to the point of not knowing about two networks in the same city in some instances). This open space to create some sort of Coalition to share experiences, tools, etc, and, most importantly, to make sure that they form part of a much bigger movement.

Additionally, in contrast with the common definition of CNs being large-scale, self-organised and decentralised networks, built and operated by citizens for citizens [51], in the African continent, most networks (83%) have less than 30 nodes. Another interesting fact is that 76% of them are either funded and/or bootstrapped externally. Only Wireless User Groups in South Africa and Nigeria follow the definition above. This is a result of having used a broad definition of Community Networks, as initiatives presented here where idenfied by their representatives as such. Mapping these initiatives to the taxonomical categories for alternative infrastructures developed in [52] could show if there is need for a new category for the African context. In this sense, existing research has looked into the build-up of local ownership in an externally initiated CN [53], however, more research is required to characterize this particular phenomenon of the CN movement in the continent. Understanding how other barriers are limiting a more organic growth of the movement it is also required and will follow up the research presented here.

We believe that, bearing in mind the many particularities of different contexts, these results are a necessary first step to start understanding the CNs movement so their potential can be maximized for a greater impact in Africa.

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8. Beyond the Last Mile: Fonias Juruá Project – an HF Digital Radio Network Experiment in Amazon (Acre/Brazil)

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Abstract

This chapter presents the experience of Fonias Juruá Project which applies digital radio on High Frequency (HF) to provide information and communication infrastructure to a rural Amazon community under-served by regular/commercial information and communication networks. We outline the historical and political background of the project and describe the novelty of the technical solution that is being developed. The beyond-the-last-mile image is evoked not only to acknowledge the material conditions of the lack of Internet connection in a particular locality but mostly to propose a critical framework to address and to question the paradigm of inclusion as an imperative for underserved third world/global south areas. Aiming to highlight the centrality of the spectrum governance and spectrum appropriation for community networks discussion and to foster exchange on the potentials of digital radio technologies as network solutions the project's experience is situated among relevant historical and contemporary initiatives in Latin America that articulate in different ways – local/community; popular; public; free; illegal/subversive – radio transmissions, Internet appropriation and direct interventions on the spectrum.

8.1. Introduction

This chapter addresses the connectivity issue by introducing the concept of *beyond the last mile*. The concept raises questions about the Internet as the only desirable solution for connectivity by arguing that other technological options can be better suited to the wills and needs of local and traditional communities in Brazilian Amazon. The solution we present here refers to radio technology working under high frequency (HF) bands, and its relevance is not only technical but also political.

Subsequently, in section two of this chapter, we introduce radio practices in the region of Jurua River, in Brazilian Amazonia close to the border with Peru. Next, we get back to trace a short genealogy of radio practices in Latin America contextualizing our current activities within a broader tradition that combines political action and communication through radio waves. Then, in sections four and five, we pass to the specifics of HF radio technology providing further details about the experiment done by our team in Amazon. Finally, we conclude remarking the importance of the concept of beyond the last mile, which is preserving an information and communication environment outside the Internet. That does not mean necessarily disconnection from the Internet, but conversely it means advocating for the option of keeping a relative autonomy in the face of it. Community networking must ensure connectivity in a way that empowers local people through technological appropriation.

8.2. Radio in Juruá: an Experiment on Brazilian Amazonia

In Amazon region of Brazil many remote rural communities are existing beyond what is commonly called the “last mile” of coverage of telephony and Internet providers. In these places fiber optic networks, local Internet providers, or terrestrial line-of-sight radio solutions are not an option due to high costs of infrastructure comprising transceivers, repeaters, towers and antennas. For several of such communities it takes one or more days by boat to reach the next landline telephone connection, however these public telephone stations have a big downtime problem and in reality often do not work. The only media access these communities have are HF radio broadcasts received by battery powered radios and Free To Air C-band satellite TV. The satellite TV reception is often restricted to two or three hours per day, usually in the beginning of the night – the time of the day when communities are turning on their power generators. Moreover, even communities and cities covered by satellite Internet have to suffer from a limited and slow access and bear high costs, which makes it impossible to take full advantage of interactive communication networks of the Internet.

Fonias Juruá Project is a collaborative initiative undertaken by an academic research group hosted by the Universidade Estadual Paulista (UNESP) gathering researchers from different Brazilian Universities (UnB, PUC-Rio, UNICAMP). This work is done in collaboration with a local team formed by people from the community of rubber tappers and family farmers of the Upper Juruá River Reserve[99] – a federal administrative territory dedicated to a concept of natural conservancy that allows traditional communities dwelling and production inside the conservation zone based on the assumption that their traditional way of life favors and enhances the protection of natural areas (ALMEIDA; 2016, pp. 14-37). The Reserve is located in the State of Acre, in Brazilian Amazon region next to the border with Peru and consists of an area of 506.000 hectares of forests and rivers underserved by regular/commercial information and communication networks. Its territory is covered by the Amazon rainforest and its Human Development Index (HDI) is among the lowest in the country.

The Federal Office responsible for Conservancy and Biodiversity – ICMBio[100] – conducted a study between 2009 and 2011 in order to elaborate a community governance plan for the Reserve. Among communication and mobility issues raised by the study there were 24 communities demanding the installation of an HF radio station (Postigo, 2010). Challenged by such a public demand for communication infrastructure in the Amazon region and by the identification of a huge potential for developments on the technology for digital radio on HF, we built a collaborative network of research in which Anthropological research and technology development work together. It must be noted that communication infrastructure is not equal to Internet connection; for reasons that will be better explained further in this article the HF radio technology was chosen as the best option to fulfill the communication infrastructure gap in the reservation area. By applying the ethnographic method to technological implementation and inspired by the ethics of free software, the project seeks to produce critical analysis of how traditional people use, appropriate and are affected by ICT as well as addressing local demands on communication and information in direct collaboration with local communities.

Raising funds for equipment, research team staff and installation has been a permanent struggle. Between 2010 and 2012 we manage to acquire 6 HF radio transceivers and to fund a few months of research work on the antenna model, energy source solutions, and other technical solutions for

99 Cf.: http://uc.socioambiental.org/en/uc/177. All links in the text were consulted in 22/10/2016.

100 Cf. : http://www.icmbio.gov.br/portal/

the digital operation on HF, including broadcasting. By 2013 the Ministry of Culture accepted an application for funding that proposed the production of 6 antennas, the acquisition of other equipment necessary for the operation and the installation of 6 HF radio stations in Brazilian Amazonia. Resources became available in the second semester of 2014. In April of 2015 the installation of 6 HF radio stations was accomplished: one station was installed in the urban area of the Marechal Thaumaturgo municipality where the Reserve is located, and the other 5 in the communities located inside the forest areas along the tributary rivers of Juruá.

In the last 10 years, attracted by access to public services such as healthcare, education and basic income as well as looking for better economic opportunities, the number of people living in the urban area has increased significantly. Almost every community member has relatives living in the city area and goes there to see them as well as to access public services, to buy goods and to do business. As a consequence, the urban radio station plays the central role as it became the hub for information exchange between the communities regarding public services, community organisation, local news, and other matters.

In order to cover the whole territory of the reserve the other 5 stations were distributed to the communities established on different rivers. Up to date we have not yet provided stations for all communities that manifested interest in receiving them. Our criteria for the communities to first receive the stations was remoteness -- the distant communities located near the headwaters of the rivers and communities located at the strategic points of the confluence of rivers, so that one station be of use to the communities located upstream of different rivers.

Each HF radio station transmits and receives signals from and to the radio transceiver connected to an antenna. Signals in this band reflect in the ionosphere (a layer of the Earth's atmosphere) providing a very large area coverage (more than 400 km). This kind of radio is typically used by amateur radio operators, military and rural communities all around the world. HF radio use is widespread in the Amazon region and during the 2015 implementation process we were able to receive and hear a considerable number of transmissions from Brazil, Bolivia and Peru, many of them in indigenous languages. We were also able to establish two-way communication with a station located in the municipality of Assis Brasil in Acre state and with a station located north of Pucallpa in Peru.

We are now entering a new phase of research and development with focus on digital applications of HF radio technology; and we plan to expand and to improve the already existing radio network with the installation of 3 more stations and add the digital capacity in all stations.

8.3. Radio Practices in Latin America

Radio technology has been used for more than ninety years to create networks between people and communities. Free and community radio stations, micro-radio, amateur radio networks, free radio, radio telephony and other movements occurred since the beginning of 1920's. In the United States in the mid-20th century amateur radio phenomena connected wirelessly more than 200 thousands North Americans (Haring, 2003), and since the 1970's, the free radio movements in Europe and in the Americas provided a way for communities to talk between themselves (Sakolsky, 1998).

Radio began in Latin America as an enterprise owned by the state and it was gradually passed to private companies. However, this media continued to accomplish, through alternative and self managed uses, an important role of delivering information to isolated, rural, less privileged areas and marginalized populations. Most of these endeavours were carried out by groups independent from State institutions or commercial interest and in many cases radio fulfilled the role of opposing political establishment and forcing it to change. Throughout the 20th century, many examples of radio experiences were successful, as independent initiatives, in providing tools for the development of organized communities and foster social struggle for better living conditions.

Carried by priest Joaquin Salcedo, Radio Sutatenza started with a homebrew HF transmitter which helped the Catholic Church to undergo a campaign of adult literacy for the peasants in the department of Boyacá, in Colombia. In the midst of the Bogotazo political turmoil in the late forties, the priest delivered what was later recognized as "the most widespread and important use of radio and other communication media for educating rural people ever seen" (Frasier; Restrepo-Estrada; 1988) It did not last long as an illegal radio since its importance was soon recognized either by the church, the Colombian State and international organisations such as UNESCO and private electronic manufacturers companies. In May 1948 – one month after the Bogotazo riots – Salcedo got a license from the Ministry of Communication to install a HF cultural radio of 250W of power[101]. In August 1949 another license was added in order to broadcast in HF with a 1kW power and in October of the same year, the Acción Cultural Popular (ACPO) was registered as the organization responsible for the Radio Sutatenza. The Radio remained aired until 1989 and achieved many of its goals related to adult literacy and cultural activities for the peasantry of the whole country. It numbers and range are impressive for a cultural and educational enterprise which started as a local unlicensed HF radio (See:

101 This is reported in: (Parejas; 1982)

Gutierrez, 2009; Moreno, 2009 & 2012). The main beneficiaries were the rural population of Colombia who engaged in cultural, educational and spiritual activities through radio. Alongside the long distance classes and broadcasts, theatre, cinema, sports and religious happenings were also developed by the ACPO, which became an important social enterprise for rural Colombia.

In Bolivia, from the late 20's to early 40's of the 20th century, radio was incipient and the few and most important broadcasters were either controlled by the state (Radio Nacional de Bolivia), group of businessmen linked with miners exploitation (Radio Illimani) or the Catholic Church (Radio Fides). By the end of the 40's self-managed radio stations started to pop up in mining districts[102]: Radio Sucre, Radio Vanguardia, Radio Huanuni, and La voz del Minero (The Voice of the Miner) organized by the Union Federation of Mining Workers of Bolivia (FSTMB). The miners' radio started in 1947 and had their most combative and conflictive time in the 60's and 70's, when Bolivia was in deep political turmoil after the revolution of 1954 and the coup d'etat of 1964. The miners' radio gained space and importance either regarding the workers struggle and as a form of organizing the workers and rural population. The experience of miners' is celebrated worldwide as a form of participatory, community driven, grass-rooted form of communication, mainly because the projects were carried by its beneficiaries, either in terms of its technical layer as in its cultural and political direction.

There is also a model of radio on which the voice, "escapes from domination of a socio-cultural economy, from the organization of reason, the mandatory scholarization, from the power of an elite, and, foremost, from the control of the enlightened consciousness" (Certeau, 1990). These radios had their dawn in Italy and France in the early 70' and have come to be known as free radios. The range of their types of expression and forms may vary enormously, but we can point out shared aspects such as the distance from commercial and industrial mode of production, search for new forms of production of sensibility, amateurism, collective forms of appropriation of the material and symbolic means of production and resistance to restrictions to free speech in legal domain. Free radios are not interested in consumer/audiences studies not even in strategies of communication, marketing and propaganda. Even the approach that puts radio as a "creative industry" and a form of cultural entrepreneurship is very far

102 See: Gumucio-Dragon, Alfonso. Miner's Radio Station: A unique communication experience from Bolivia. Melled, 2004. & Fernando Reyes Matta (ed.) Comunicación Alternativa y Búsquedas Democráticas (1983), Santiago, Chile: ILET/Friedrich Ebert Stiftung. & Herrera Miller, Karina (2006). ¿Del grito pionero… al silencio? Las radios sindicales mineras en la Bolivia de hoy, La Paz, Friedrich Ebert Stiftung, Instituto LatinoAmericano de Investigaciones Sociales (FES-ILDIS)

from the point of view defended by them. The political approach of unconventional and of illegal radios uttered a clear position that distances them either from Capitalist Market and from institutional forms of governance: "a word finally found. Seemed plausible to invert the official information and make another true to be heard, free from money and power"[103].

In Brazil, since the tradition of community radio was less significant than in other South American countries (the first bill for community radios in Brazil was passed only in 1998), the appearance of the Free Radio movement was embraced largely in cities and intellectual circles countrywide (Magri, Masagão & Machado, 1986). In the 80's, French thinker and free radio activist Felix Guattari spent some time in Brazil in debates, conferences and other academic and cultural activities. Amongst his main interests was subjective production through "minor voices" and Free Radio such as the Italian and French radios appeared to be be good references for the Brazilian scenario at the time. Throughout that decade, many Free Radio experiences appeared in the cities of the Rio de Janeiro and São Paulo states, notably in educational and cultural institutions. Most of them lasted long enough to mark the free radio movement as one of the most significant in the media activism landscape of Brazil until today[104].

Also based on the same principles of community and free media, in Argentina, a group of activist initiated a movement for providing autonomous wireless infrastructures for communities mostly in the countryside. Some initiatives of Free/Community radios and television organized by the network share technical, political, editorial and artistic contents so the whole network can replicate their knowledge and apply it for their own needs. The RNMA[105] (Red Nacional de Medios Alternativos) is an initiative to congregate the experiences and lists radios, televisions, news agencies, graphical and technical support as part of the broad network[106]. DTL[107], as one of the technical supporters, provides collective workshops on building transmitters, antenna as well as community engagement and media politics.

The radio technology of VHF and HF transceivers (two-way communication system, on which you can talk and listen through the same device) for voice and radiotelegraphy was used by Cuban revolutionaries

103 Collectif radios libres populaires, Les radio Libre. Petite collection Maspero, 1, Place Painlevé - Paris V, 1978. [Translated from brazilian portuguese] translation by Novaes, Thiago & Maureau, Raphael, As Rádios Livres, cf.: http://radiolivre.org/?q=node/777 .

104 Cf.: Cf. http://www.radiolivre.org/

105 Cf. : National Network of Aternative Media: http://www.rnma.org.ar/

106 Cf. : http://www.rnma.org.ar/quienes/compartimos-la-red

107 Cf. : https://dtlcomunicacion.wordpress.com/

transmitting in HF from Sierra Maestra and also in emergency situations like earthquakes alerts in Chile. One innovative experience with the same technology which occurred in the beginning of the first decade of the 21th century was the EHAS[108] (Enlace Hispano Americano de Salud – Hispano American Health Link) project. The EHAS project proposed and implemented digital communication services, such as e-mail, using VHF and HF transceivers in Peru. The system was conceived to improve healthcare services by connecting health facilities in rural areas. Developed by Rural Telecommunications Group (GTR) of Catholic University of Peru, the system used free software and was comprehensively described in the book "Redes Inalambricas para Zonas Rurales" (Araujo, 2008). The project showed the feasibility of the use of digital radio technologies using standard radio transceivers for HF and VHF and regular computers for a low bit-rate data transmission. The implementation of the digital services, nonetheless, failed to achieve broad usage:

"... However, this solution proved far too complex and it was very difficult to train local technicians to maintain the data services. As a result, medical technicians did not adapt to services they had never used before, and networks functioned exclusively as voice-only." (Rey-Moreno, 2013).

In the end, a WiFi network was built to support the digital services in health care centres.

8.3.1 Radio Politics and Unlicensed Spectrum

Having in consideration all those initiatives that outline the interrelation of political action and radio technology, we may argue that current practices of community networking are built upon a techno-political tradition that goes along the whole 20th century in Latin America. At the end of that century the opening of a portion of the radio spectrum to unlicensed use and the introduction of WiFi (WLAN) routers in the market have expanded the potential of political action throughout radio waves. A fair and minimal definition of the unlicensed spectrum could remain restricted to the fact that it is a portion of the radio spectrum that does not requires from the user any prior licensing permission to operate on it as long as the equipment comply with the standards set by responsible regulatory agency. This fact opens up an extensive political and regulatory discussion about radio spectrum usage and licensing models by opposing exclusive licensing to the open/unlicensed model. This Wi-Fi (WLAN) technology was experimented with and further developed by enthusiasts and activists even before becoming one of the technologies applied by ISPs or telecom

108 Cf. : http://www.ehas.org/

operators. Not surprisingly, WiFi community networks are connected to other movements that put together technology and politics: hacking, free software movement, independent media, free radios, indigenous and traditional people, quilombolas (maroons), anonymity and privacy protection movements.

The unlicensed spectrum has been regarded as an important asset to enhance connectivity especially through community networking. But, limited as it is today to small portions of the entire radio spectrum, and given its short range propagation characteristics, the unlicensed spectrum is not enough to guarantee broad connectivity. In this sense, the fight for the spectrum occupancy by community networking initiatives demand taking over licensed spectrum within localities where the license holders do not make proper use of it by not providing any kind of connectivity. Several underserved communities in rural Mexico are running their own cellphone network infrastructures with the support of Rhizomatica[109], organization. Enrollment in the network is free of charge for the community members who are only charged for making calls to phones that are not part of the community network - i.e. operating within a subscription to commercial network operators. These national and international calls are charged low cost and they are technically made possible through Internet voice over IP (VoIP) technology. Recently these communities have acquired the right to operate under a licence granted by the Mexican government to the not for-profit-organizations[110]. This achievement of the licence usage represent a precedent and an important step in the direction of breaking telecommunications monopolies. Moreover it empowers communities by providing conditions to organize themselves through building autonomous communication systems.

8.4. About High Frequency (Hf) Radio Band

Up until the 1960's the use of the HF technology was widespread around the world connecting different continents. With the adoption of the satellite communications and installation of many fiber cables its use gradually diminished, but it's still in use in many rural areas.

In comparison to other digital networks like WiFi, LTE telephony system or Digital TV, the use of a digital communication system in HF has the advantages of providing a much greater coverage area with a simple and easy to maintain network, thanks to the skywave propagation mode,

109 Cf. : https://rhizomatica.org/

110 Cf.: https://www.theguardian.com/world/2016/aug/15/mexico-mobile-phone-network-indigenous-community

but on the other hand, the bit rate possible with the current HF transceivers are much lower than what is possible using other digital systems on higher spectrum bands. The use of digital communications in HF is seeing renewed interest in recent years due to the advances in digital modulation techniques and the availability of high speed digital signal processors. However, at the moment these advances are more broadly available to the military, for example, in the systems based on STANAG 5056 (NATO, 2015) standardized by the North Atlantic Treaty Organization (NATO).

Recently some big HF international broadcasters, like the All India Radio, the Vatican Radio and the BBC, started transmitting using digital technology with the Digital Radio Mondiale (DRM) standard and amateur radio operators started using modified military radio standards. However no widespread use of digital two way communication on HF are used by civilian people living in areas with low or no any communications infrastructure.

To date there is no commercially produced two way digital radio equipment that can be purchased and used by the non-military community for high data rate communication in the HF radio band. This project aims at development of an easy to use and reproducible HF digital radio communication solution to connect places and communities, making use of widely available HF radio transceivers connected to embedded computer, which runs the modem (modulation/demodulation) part of the system.

The advantage of using HF communication is the possibility to reach places beyond the line of sight because of the characteristic of propagation in this frequency band where the wave bounces in the ionosphere layer of the Earth's atmosphere (skywave propagation).

8.5. Digital Radio on Hf for Amazon Region

The current stage[111] of the Fonias Juruá project involves field trials of the digital HF transmission/reception chain in terms of robustness and reliability, in order to better understand the effects of different transmission parameters, power levels and antenna configurations. Also an easy to use interface running in an embedded computer is being developed in order traditional people can use the solution to its full potential. In the September 2016 we managed to send and received files and pictures between the urban area of Marechal Thaumaturgo and one location inside the reservation, and between two places inside the reservation, in order to validate

111 Cf.: http://postulaciones.programafrida.net/ideas/ver/19983

our assumption that the selected digital radio system worked well with our setup.

The solution we are developing is meant for people that do not have any communication infrastructure, but it could also be used by communities with few or unaffordable communication means or as a backup solution. The infrastructure already installed is composed by HF radio transceivers installed in 6 local communities. The technological components are stock HF radios (just like the ones used by ham-radio or marine operators) that are connected to antennas and usually powered by solar panels and batteries. Each node is composed by HF transceiver, interface between radio and embedded computer, the embedded computer itself, antenna, battery, solar panel and cables to connect all the equipment -- the full node costs around 6000 USD.

In regards to functionality, the radio has two operating modes. One is the voice mode, in analog SSB (Single Side Band) modulation, and the other mode is for digital data transmission, in which the signal is generated by an embedded computer using Software Defined Radio (SDR) techniques and sent to the radio via a special interface. When transmitting digital data over the radio a low bit rate connection can be established in order that documents like pictures, texts, spreadsheets can be transmitted. The bitrate is limited by the small passband (typically 2.5kHz up to 3kHz) of the radios, initially designed for voice, that eventually could be overcome with small modifications in the radio or with the use of specialized HF radios with wider bandwidth.

The modulation chosen for the digital transmission is based in the Digital Radio Mondiale (DRM), which is a digital radio broadcasting standard which works in HF band and is based on OFDM (Orthogonal frequency-division multiplexing) technique for encoding data into multiple carriers. Other systems based on OFDM are Digital TV systems like ISDB-T, WiFi, 4G LTE telephony, but all of them works on higher bands of the spectrum, like UHF (Ultra High-Frequency). As the HF transceivers have a small passband, meant for voice communication, and DRM was created for radio broadcasting, which uses a wider bandwidth, a variation of DRM using a smaller bandwidth called HamDRM or WinDRM was developed. This variation of DRM was developed based on the first open source implementation of the DRM system using Software Defined Radio techniques (Kurpiers, 2003), and is called QSSTV[112].

The protocol selected to work in the multiplex level works with DRM and is called Multimedia Object Transfer (ETSI, 2006). The Multimedia Object Transfer protocol (MOT) allows the transmission of files over a DRM

112 Cf. : http://users.telenet.be/on4qz/

signal in a cyclic way, in a mode called carousel, which consists of transmitting the content repeatedly, just like as if the data is split in parts and put in a carousel. Ham-radio operators evolved the protocol in order that the receiving station can ask the transmitting station to re-transmit blocks of data which the reception was not successful, if any. With this feature called Bad Segment Request (BSR) added to the MOT protocol, this is the protocol used for carrying the files over the digital signal used in the project. Also the Brazilian DTV middleware, called Ginga, which provides support for transmit, receive and execute multimedia interactive applications in DTV, was adapted to work with DRM and the MOT protocol by Telemídia Laboratory at PUC-Rio University (Diniz, 2015).

Just like in EHAS (Araujo, 2008) project in Peruvian Amazon, the modem accepts different modulation and robustness parameters, which need to be adjusted for each propagation condition. With the radios in use by Fonias Juruá project, the ICOM IC-78, running at 40W forward power in digital mode, with a Carolina Widow design antenna tuned at 80m band (3,545 kHz) we realized that using 4-QAM modulation for the OFDM carriers gave better results in terms of successful reception than 16-QAM (16-QAM provides higher bitrate than 4-QAM). The achieved bit rate was around 2kbit/s. Left to test was the BSR (Bad Segment Request) feature, which allows the receiver to send a message back to the transmitter with the list of the data segments not correctly decoded in order to allow us to use a higher bit rate transmission (by using a higher order modulation with a higher bit rate error rate). Also, not evaluated in the trials was the effect of the non-linear amplifier on the radio in the OFDM carriers constellation. The system is ready to be used with radios with wider bandwidth as DRM has operating modes up to 20kHz of bandwidth, allowing as much as 64kbit/s, but in order to achieve a wider bandwidth transmission, the standard voice-designed radios need to be modified, in order a wider passband can be achieved, or specialized radios can be used, like ApacheLabs[113] radios, which also include non-linear pre-correction circuitry, very good for digital transmissions.

The EHAS project used also an OFDM modem in HF, called "newqpsk", provided by the *soundmodem* software, but in the upper network layers, a much complex stack is adopted, composed by AX.25 packet radio protocol, TCP and IP protocols, queue management (UUCP) and the mail server (Postfix), plus other routing and system management functionalities (Araujo, 2008). The high complexity and the lack of a simple to use interface of the EHAS communication system for HF (and VHF) seems to indicate that a simple solution with an easy to use interface are very important for a successful use of digital services over standard HF radio

113 Cf. : https://apache-labs.com/

transceivers. In this regard, we believe that the collaboration with the local communities and the participation of the project's local team not only in the tests, but also in the designing of the services and in the development of the interface, amplifies our chance to succeed.

In comparison to satellite, fibre cables and radio technologies operating in higher frequencies (VHF, UHF, SHF), this solution costs less, requires neither regular subscription fee nor complex network maintenance. The operation of the equipment can be done by anyone after a simple training is provided. The sustainability of the infrastructure is in that there are no periodic payments to any provider, no complex infrastructure to maintain and broad availability of the equipment.

In relation to the services planned to be delivered to the communities, we already defined two pilot experiments that will be held in two different stations taking advantage of their particular special features: one located inside a health centre where a nurse[114] operates the radio station; the other one is located very near to an elementary school. In both cases, the ideia is to develop an easy to use and useful system which involves the transmission of digital files adapted to specific needs of the health centre and of the school.

8.6. Conclusion: Beyond the Last Mile

If continued and elaborated, we believe this research has potential to make a significant contribution in the area of exploration of new alternative forms of digital communication technologies for Amazon rural areas and for other contexts that share geographical and social characteristics. This contribution will be both valuable for the research and development of digital radio technology using HF as well as for the academic research within telecommunications engineering, computer and social sciences and humanities fields.

Fonias Juruá Project applies a bottom-up approach that can also be considered as a critical framework to overcome the problem of connecting the so-called "next billion" but an alternative one that avoids the paradigm of inclusion. After all, this is a case of a communication infrastructure developed in collaboration with the local community and run by the local community that represents a path of resistance against mainstream technologies as well as a non-commercial approach to address the problem of

114 This nurse became an important collaborator of the Fonias Juruá project. He is from Peru, where he received training for radio operation applied to telemedicine programs.

connectivity. The network runs autonomously from any kind of backbone and directly connects small groups scattered throughout a rain forest reservation area.

We evoke the image of beyond the last mile as a way to draw the attention to the fact that there are contexts where other network designs might fits better than internet, as such the HF radio in Fonias Juruá project. An image that therefore helps to escape from the uncritically accepted imperative of the Internet, which is based on the assumption -- a colonial assumption -- that the access to the Internet in its contemporary dominant form[115] is an indispensable and unavoidable tool for human development, democracy and good living (*buen vivir*). Of course we do recognize the potentials of the Internet, but we do also believe that our historical moment urges us to re-think its implications mainly in the field of political and social control.

The HF digital radio network offers us the opportunity to experience an out-of-the-Internet experiment that seeks political and technological autonomy, not only at the level of the use but also at the level of development, at same time it advances digital technologies developments for information and communication systems.

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115 Here we refer to the hegemonic model of commercial social networks platforms, concentrated and controlled by a few US companies, whose services are based in massive data storage and data processing over user-generated data, with close ties and intense collaboration with american government – and its allies' – agencies of security and intelligence. This model also depends on technologies submitted to accelerate obsolescence/innovation cycles. We also have in mind here cutting-edge massive access providing projects such as Google Loon project (cf.: https://www.solveforx.com/loon/) and Facebook's Internet.org projetc (cf. : https://info.internet.org/en/).

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9. Caracterización de los Espacios en Blanco del Espectro Radioeléctrico en la Banda UHF en Países Emergentes: Caso de Estudio del Estado Mérida.

Maureen Patricia Hernández González

Abstract

TV white spaces represent an alternative to various problems such as the shortage of spectrum; the challenge of bringing connection to remote locations or even deploying community networks by using portions of underused spectrum. TV White Spaces (TVWS) are spaces that were left unused due to the transition from analogue to digital television or simply because in certain regions TV operators do not see a return on investment and therefore these frequencies are available for use; however to declare a chunk of spectrum underused monitoring technique must be performed.

In this work a census of the electromagnetic spectrum between 300 MHz and 900 MHz was performed, this frequencies belong to the Ultra High Frequency band (UHF), the measurement was performed with low-cost devices so that these measurements will be replicated in developing countries, where they lack of the expensive technology generally required for such surveys. A measurement framework was developed based on this experience and previous experiences demonstrating that it is possible to make an organized and structured census of a spectrum portion, to provide insight into the state of the spectrum, thus justifying the use of these frequencies for the deployment of community networks as well as for cognitive-radio use.

Resumen

Los espacios en blanco de televisión representan una alternativa a diversos problemas, tales como, la escasez de espectro; el reto de llevar conexión a lugares remotos o incluso el despliegue de redes comunitarias mediante el uso de porciones de espectro sub-utilizado. Los espacios en blanco de televisión son espacios que han quedado desocupados debido a la transición de la televisión analógica a la digital o simplemente porque en ciertas regiones los operadores de televisión no ven un retorno de inversión y en consecuencia estas frecuencias están disponibles para su uso; sin embargo para poder declarar un espacio sub-utilizado debe realizarse una comprobación técnica del espectro.

En este trabajo se realizó un censo del espectro electromagnético de 300 MHz a 900 MHz, pertenecientes a la banda *Ultra High Frequency* (UHF), con dispositivos de medición de bajo costo de manera que estas mediciones sean replicables, en países en vías de desarrollo, que carecen de la costosa tecnología generalmente requerida para realizar dichos censos. Se construye un marco de medición basado en esta experiencia y experiencias previas arrojando un censo del espectro con diferentes dispositivos de bajo costo que demuestran que es posible realizar un censado organizado y estructurado de una porción del espectro que sirva como una fuente válida del estado del mismo y en consecuencia una fuente válida para la justificación del uso de estas frecuencias en función del despliegue de redes comunitarias o de radio cognitiva.

9.1. Introducción

Sumado a grandes variables la transición de la televisión analógica a la televisión digital, permite el crecimiento de dichos espacios en blanco presentándolos con más fuerza como una alternativa a la saturación del espectro. Todo esto crea el escenario perfecto para transformar el desuso de ciertas bandas de frecuencia en una ventaja para el despliegue de redes inalámbricas, redes comunitarias, plataformas de datos[116], redes en campus universitarios[117] y redes de sensores para innumerables usos como siste-

116 Realtek, RTL2832U DVB-T COFDM Demodulator + USB 2.0 http://www.realtek.com.tw/products/productsView.aspx?Langid=1&PFid=35&Level=4&Conn=3&ProdID=257.

117 M. Bagula, M. Zennaro. “WHITENET: A WHITE SPACE NETWORK FOR CAMPUS CONNECTIVITY USING SPECTRUM SENSING DESIGN PRINCIPLES”

mas de prevención de desastres tales como contaminación de las aguas[118], entre otros.

Las características superiores de propagación de la tecnología TVWS hacen que sea especialmente adecuado para conectar a las comunidades remotas y en consecuencia habilitar allí el despliegue de redes comunitarias o comunicación con la última milla. Debido a su rango y la asequibilidad, las tecnologías inalámbricas ofrecen la mayor esperanza para salvar la brecha digital de manera efectiva. Tener mediciones reales de la ocupación del espectro real puede allanar el camino para un uso más eficiente del espectro. La detección de actividad es de fundamental importancia para muchas aplicaciones inalámbricas, incluyendo la asignación de canal de radio cognitiva y de radiolocalización. Por lo tanto, los espacios de espectro no utilizado podrían ser utilizados dinámicamente por quienes han sido asignados para el uso de dicha banda de frecuencia. Para la planificación e implementación de estas redes, es crucial conocer la utilización actual del espectro electromagnético.

Este trabajo se basa en el uso y configuración de dispositivos de bajo costo que puedan realizar procesos de escaneo de cierta porción del espectro radioeléctrico, ya que esto es una pieza fundamental para la explotación de las frecuencias sub-utilizadas.

Este documento está organizado de la siguiente manera, I. Introducción. Contiene los antecedentes y marco teórico. II. presenta los dispositivos III. Marco de recolección. IV. Resultados de las mediciones y la simulación del canal ULA TV. Se muestran caracterizaciones de la porción del espectro seleccionado. IV. Conclusiones y recomendaciones.

9.1.1. Antecedentes

a) Arcia-Moret et al. presentaron [119] en varias investigaciones [120] un conjunto de medidas hechas con un dispositivo de bajo costo llamado WhispPi. La campaña de medición consistió en varias etapas. En la primera rango de medición osciló entre 300 MHz y 960 MHz*,* en aquella ocasión se encontró que el espectro se encontraba en gran parte sub-utilizado. Estas mediciones arrojaron como resultado que hay más de 80% de espacios en blanco en las regiones rurales y en regiones urbanas hay más de 60% de espa-

118 A. Khan y L. Jenkins. Undersea wireless sensor network for ocean pollution prevention.

119 A. Arcia-Moret, E. Pietrosemoli y M. Zennaro, “WhispPi: White space monitoring with Raspberry Pi”

120 Zennaro, M. y Arcia-Moret A , “TV White Spaces: A pragmatic approach”.

cios en blanco localizados en las frecuencias entre 300 MHz y 900 MHz.

b) Se presenta una recolección de datos [121] hecha con un dispositivo de bajo costo llamado RF Explorer, el cual permite el análisis de las bandas de frecuencia desde 240 MHz hasta 960 MHz, una antena externa omnidireccional, una laptop y un GPS. Esta campaña consistió en la medición de 14 puntos específicos de la ciudad de Trieste en Italia, la cual abarcaba zonas rurales, semi-rurales y urbanas midiendo desde 400 MHz hasta 800 MHz, donde se tenía bien conocida la actividad espectral en el área y las mediciones mostraron estar en concordancia con la actividad esperada.

Esta y otras experiencias, como la realizada en investigaciones similares[122], nos indicaban que las mediciones hechas con estos dispositivos tendrían un alto grado de fiabilidad. Este trabajo realiza una comprobación entre mediciones y comportamiento esperado en la sección V. Resultado, Simulación de canal de TV: ULA TV

Aunque A y B son realizados con dispositivos de bajo costo equiparables a los utilizados en este trabajo una comprobación simultanea con ambos tipos de dispositivos no fue realizada, por otro lado no hubo un levantamiento espectral con campanas continuas durante un determinado periodo de tiempo, en **A** porque consto en campañas de recolección de un solo recorrido y en **B** porque se trato de mediciones en puestos específicos durante una jornada específica.

La manera de comprobar el espectro puede variar en relación a muchas características, existen analizadores de espectro que poseen características no favorables en el entorno de este trabajo, por ejemplo, su costo es inabordable para una investigación y en segundo lugar, en su mayoría, poseen características físicas tales como tamaño, peso y necesidad de potencia que los perfilan como dispositivos estáticos.

9.1.2. Marco Teórico.

Se considera que los lectores de ese documento están familiarizados con los términos frecuencia, potencia, bandas de guarda, espectro electromagnético y banda UHF, además de esto los siguientes conceptos se consideran necesarios.

121 M.Zennaro, E. Pietrosemoli, A.Bagula, S. Nleya. “On the Relevance of Using Affordable Tools for White Spaces Identification”.

122 H. Mauwa, A. Bagula y M. Zennaro. “Exploring TV White Spaces for Use in Campus Networks”

a) TVWS.

Los espacios en blanco de televisión (TV *White Spaces*) es un término que se refiere a partes del espectro de radio con licencia que los licenciatarios no utilizan todo el tiempo o en todas las ubicaciones geográficas. Los espacios de televisión en blanco son identificados de tres maneras[123]:

- Detección del espectro mediante censo.
- Canal piloto (*beacon*).
- Base de datos de localización geográfica.

9.2. Dispositivos

a) ASCII 32

Tal como se describe en[124], es un dispositivo de bajo costo que sirve para identificar y geo-etiquetar el espectro de radiofrecuencia en la banda de sub 1 GHz y tiene embebido un chip GPS (*Global Positioning System*) para la captura de la posición geográfica.

b) WhispPi

Arcia-Moret et al. plantean en 4 un sistema que cumple con estos requisitos, de fácil manipulación y bajo consumo de energía. El sistema se cuenta con cuatro componentes: Un Raspberry Pi (RPI), un analizador de espectro: RF Explorer, un GPS y una pequeña batería.

c) RTL-SDR Dongle

Es un dispositivo de radio definida por *software*, basado en el chip demodulador DVB-T (*Digital Video Broadcasting*) de Realtek's y el chip sintonizador de Rafael Micro's R820T.Ccon este modelo específico se puede sintonizar desde 24 MHz hasta 1766 MHz.

123 http://www.hindawi.com/journals/ijdmb/2010/236568/

124 M. Zennaro, E. Pietrosemoli, A. Arcia-Moret, C Mikeka, J Pinifolo, C Wang, S Song. “TV White Spaces, I Presume?: The Quest for TVWS in Malawi and Zambia”.

Dispositivo	ASCII 32	WhispPi	RTLSDR D.
Costo (USD)	< 200 No disponible	340	25
Velocidad de muestreo[1]*	1,31 muestras/s	0,41 muestras/s	0,22 muestras/s
Ambiente de con-figuración.	ARDUINO IDE[2]	Scripts	Scripts
Dependencias fundamentals	Baterías AA. Librerías del en-torno[3]	Dependencia entre dispositivos. Cargador portátil	Uso de librería de Osmo RTL[4] o GNURadio Velocidad de lectura de puerto USB

1 Modificables mediante mejoras propuestas en conclusiones.
2 https://www.arduino.cc/
3 ascii32.h, SPI.h, SD.h, gps.h.
4 http://sdr.osmocom.org/trac/wiki/rtl-sdr

Tabla 1. Comparación de dispositivos

En la tabla 1 se observa una comparación general de los dispositivos utilizados en este trabajo con el fin de ubicar al lector con respecto a las características de cada uno.

9.3. Marco de recolección

En la ciudad de Mérida se escogieron dos zonas: una zona superior identificada como **A** (Figura 1) que representa el sector de medición de la Avenida Los Próceres, de la ciudad de Mérida, la cual se clasifica como una zona suburbana en base a criterios expuestos por Brown et al.[125]; cuenta con una densidad de población baja y medianamente baja, constituida por una densidad neta máxima de 265 habitantes por hectárea[126]. El recorrido tal de esta zona fue de 7,2 km.

125 T. Brown, E. Pietrosemoli, M. Zennaro, A. Bagula, H. Mauwa y S. Nleya. “A Survey of TV White Space Measurements. In: e-Infrastructure and e-Services for Developing Countries”.

126 GACETA MUNICIPAL. S U M A R I O O R D E N A N Z A S. Reforma de la Ordenanza de Lineamientos de Usos del Suelo, referidos a la Poligonal Urbana del Municipio Libertador del Estado Mérida. 2002. En Depósito Legal Nro. 79-0151 Extraordinaria Nro.58 Año III.

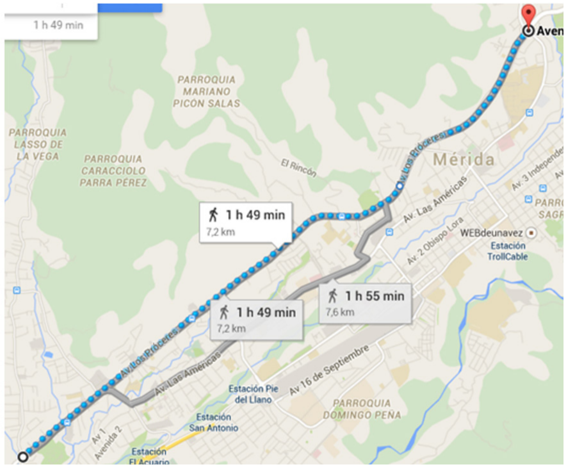

Figura 1. Recorrido para la recolección de actividad espectral en la zona sub urbana: Av. Los Próceres. (Trazado en Google Maps)

El segundo sector representa una zona urbana identificada como **B**, ubicada en el casco central de la ciudad. Posee una densidad de población medianamente alta, con una densidad neta de 590 habitantes por hectárea14. La distancia del recorrido total para esta zona es de 5 km.

9.3.1 Procedimiento

Se procedió entonces a realizar una campaña de medición de la siguiente manera:

1. **Escoger la zona a medir.** Se realizaron las campañas de medición de manera secuencial.
2. **Escoger las frecuencias a analizar.** Se midió desde los 300 MHz hasta los 900 MHz
3. **Preparar los dispositivos a utilizar.** Se procede a verificar que se tienen los dispositivos con las características mínimas necesarias para su funcionamiento adecuado
4. **Realizar medición.** Se realiza el recorrido planeado con los dispositivos seleccionados de manera simultánea.
5. **Análisis.** Una vez que se culmina la campaña se procede a analizar los resultados. Posteriormente y previa justificación, se puede realizar otras campañas para comprobar los mismos:

5.1. Realizar mediciones específicas para comparar resultados. Con el fin de indagar en ciertos rangos de interés se realiza el mismo recorrido midiendo con un dispositivo distinto al utilizado en la jornada previa.

6. **Obtener conclusiones.** Proceso final de conclusión de acuerdo a resultados.

En este trabajo el paso 5.1 correspondió a una medición de comparación mediante el Dongle, utilizando un rango menor de frecuencias enfocado a la porción del espectro de interés. Se escogió la porción del espectro utilizada por el canal de Televisión ULA TV ubicado en el canal 29 de UHF abarcando desde 560 MHz a 566 MHz.

9.4. Resultados

Análisis de resultados en campañas de medición con dispositivos simultáneos ASCII 32 y WhispPi [127]

En la Tabla 4 observamos la comparación de los resultados obtenidos por los dispositivos en la zona urbana. Se observa una similitud entre casi todos los resultados de la medición, solo difieren los resultados en el promedio de la potencia máxima donde el ASCII 32 muestra haber capturado señales más potentes, este mismo comportamiento se observa en la zona suburbana.

Dispositivo	WhispPi	ASCII
Promedio Potencia min (dBm)	-114,08	-115, 33
Promedia Potencia máx. (dBm)	-52	-40,16
Potencia promedio (dBm)	-105,2	-105,6
Promedio % de Dev Estándar	0,84	1

Tabla 2. Comparación de resultados: ASCII 32 versus WhispPi en zona urbana

127 El análisis detallado individual de cada una de la campanas de medición de cada uno de los dispositivos se pueden proporcionar mediante una solicitud al autor.

Se realizaron comparaciones entre los dispositivos de medición y se realizó una comparación entre los distintos umbrales que se pueden utilizar a fin de replicar la experiencia ejecutada por Zennaro6. Los resultaros generales en la zona urbana son presentados en la Tabla 2.

a) ASCII 32 versus WhispPi.: 1/12/2015 - Casco Central de la ciudad (zona urbana)

Se observan similitudes con respecto a la ocupación en la primera observación, donde se presenta una alta ocupación en los canales centrales y finales de la porción del espectro censado, realizando una comparativa del comportamiento de la ocupación con respecto a la variación del umbral se evidencia que este comportamiento se mantiene llevando el umbral varios decibeles milivatios por debajo del valor estimado inicialmente donde hay canales que definitivamente permanecen ocupados como es el caso de las frecuencias comprendidas entre el canal 80 (868 MHz - 872 MHz) hasta los 900 MHZ, correspondientes a las frecuencias de uso de telefonía celular, como se observa en la Figura 2.

La variación del umbral demuestra resultados consistentes a lo largo de las campanas realizadas, es decir, no se encuentran espurios o falsos positivos (o negativos) en las campanas analizadas, esto se realiza como una confirmación a fiabilidad del censo. Por otro lado se evidencia que los dispositivos arrojan resultados similares, más allá de pequeñas variaciones debido a características propias de cada uno.

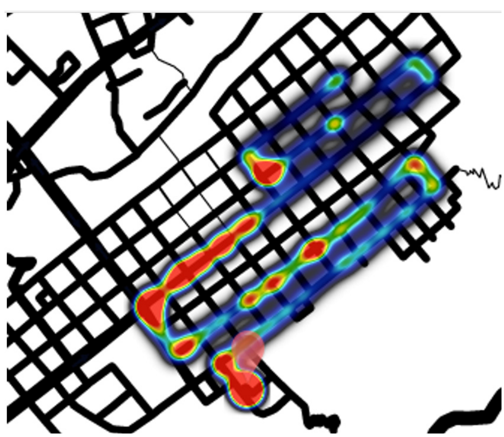

Figura 2. Mapa de calor realizado con Zebra RFO que muestra la ocupación del canal 23 (524 MHz a 530 MHz) en zona urbana de la Ciudad de Mérida, con el dispositivo ASCII 32.

Finalmente los resultados obtenidos se presentan en consistencia con campañas anteriores en la misma ubicación y bajo condiciones similares4 recordando por supuesto que esta vez se está realizando una triple verificación (una por dispositivo) de los resultados.

9.4.1. Simulación canal de TV: ULA TV

Se decidió, basado en la información bien conocida sobre el canal de TV "ULA TV" [128] que opera en la ciudad de Mérida, realizar una simulación de la cobertura de esta televisora mediante su planta base de transmisión en torno a la ciudad andina, con el fin de comparar los resultados obtenidos con los dispositivo y los esperados con respecto a la información sobre la radiodifusión de esta televisora local.

ULA TV es la televisora de la Universidad de Los Andes, la cual transmite en el canal 29 UHF. La planta de donde se transmite la señal está ubicada a unos 10 km del casco central de la ciudad.

En este caso se puede observar el relieve montañoso, que caracteriza la ciudad andina, el cual deja en evidencia las zonas donde no alcanza a llegar la señal, como se evidencia en la Figura 3.

La zona verdosa corresponde a una potencia de señal alrededor de -95 dBm. La zona amarilla corresponde a aproximadamente -76 dBm o valores que oscilan alrededor del mismo, mientras que la zona naranja representa aproxima valores al -63 dBm. Finalmente la zona roja representa -50 dBm o valores superiores

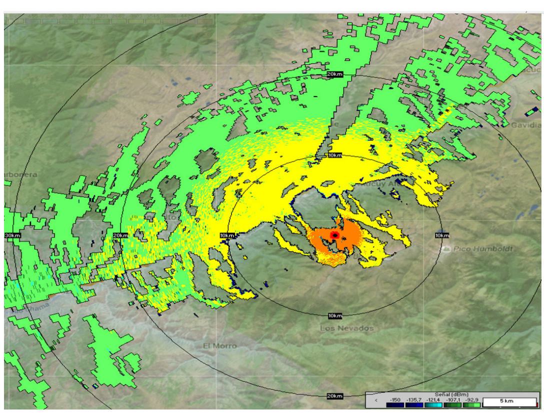

Figura 3. Radio de cobertura desde una vista satelital sobre la ciudad de Mérida.

128 ULA TV Televisora de la Universidad de Los Andes. http://tv.ula.ve/

Acercamiento con RTL Dongle

Con el objetivo de observar el comportamiento espectral en las frecuencias del canal de televisión ULA TV, se realizó una prueba en los mismos recorridos (urbano y suburbano).

Esta prueba fue ejecutada con el Dongle mediante un sistema llamado DongleWhiteScanner (DWS)[129] reduciendo el ancho de banda de medición a 6 MHz comprendidos entre las frecuencias desde 560 MHz hasta 566 MHz, correspondientes al canal 29 UHF donde transmite dicha televisora. El promedio de la potencia obtenida entre los dos escenarios fue de -47,1 dBm.

Se observa entonces que el canal 29 UHF cuenta con una ocupación alta, presentando picos en las frecuencias alrededor de los 561 MHz y 566 MHz y una ocupación casi total, lo cual sería concordante con los resultados esperados en esta simulación.

9.5. Conclusiones y próximos pasos.

Se realizo un censado del espectro radioeléctrico en la ciudad de Mérida, con el uso de dispositivos de bajo costo, fácil adquisición y configuración; tomando en cuenta experiencias previas se realizo una comparación simultanea para verificar la fiabilidad de los resultados, de igual manera se abordaron estrategias como variación del umbral y comparación con tabla local de atribución de frecuencias, todo esto para confirmar que el uso de estos dispositivos para el censado es una estrategia no solo valida sino una alternativa real que puede acelerar el proceso de solicitud de bandas de frecuencia para el uso en redes comunitarias y de radio cognitiva.

Se logró evidenciar los desafíos en el proceso de medición, como por ejemplo: calibración de los equipos, necesidad de personal mínimamente capacitado, costo de los dispositivos para implementar mejoras físicas, entre otros. Sin embargo, se pretenden generar expectativas en un futuro cercano con respecto al uso de dispositivos de bajo costo, como los utilizados en este trabajo (no se conocen configuraciones de menor costo hasta el momento) en procesos de medición que sirvan como entes colaboradores ya sea para uso de las comunidades, los gobiernos o la verificación de políticas de acceso y compartimiento del espectro.

Las campañas de medición, realizadas en su mayoría con el dispositivo WhispPi y el dispositivo ASCII 32 de manera simultánea, demostraron

129 https://bitbucket.org/mauhernandez/donglewhitescanner/

que los resultados pueden variar en algunos decibelios. Esto depende de las características de apreciación de los dispositivos, por ejemplo, el ASCII 32 tiene una sensibilidad mayor a la del RF Explorer, dispositivo encargado, en dicha configuración, de realizar la captación de la potencia. Esta observación sobre la sensibilidad del dispositivo ASCII 32 quizá se deba a que la frecuencia de muestreo del mismo es mayor que la del WhispPi permitiendo de esta manera que el dispositivo capture más ruido del normal, esto pretende ajustarse en próximas investigaciones.

Es importante destacar, que en algunos casos, los espacios en blanco encontrados no son contiguos, por lo que se dice que el "espacio en blanco", como un total, se presenta de manera fragmentada; el uso de una frecuencia específica para ser utilizada con dispositivos inalámbricos está afectada por su contigüidad y esto debe tomarse en cuenta al momento de cuantificar los espacios. Solo por el hecho de que un canal no presente actividad, no significa que es un espacio en blanco capaz de ser utilizado para algunos servicios, se debe investigar para qué servicio desea ser usado y con base a esto decidir si se adecúa su uso o no, como lo propone[130] un canal de 20 MHz para el estándar IEEE 802.11 no puede funcionar en un determinado lugar si los espacios en blanco de canales de 8 MHz no son contiguos.

El uso de nuevos dispositivos emergentes como el RTL SDR Dongle representa una nueva oportunidad de realización de campañas de recolección masiva de datos y en consecuencia utilización de estos espacios. Existe una probabilidad muy alta que dispositivos como estos formen cada vez más redes de nodos de censores[131], por lo que se motiva a la continuación de investigaciones e implementaciones de la misma naturaleza.

Se espera en próximas investigaciones realizar una mejora al uso del Dongle como lo muestra. Una por ejemplo Pfmamtter et al.20 donde se implementa una explotación de la capacidad del RPI mediante el uso del GPU (Graphics Processor Unit) para el procesamiento de la FFT. De igual manera se pretende sincronizar la frecuencia de muestreo de los dispositivos simultáneos para obtener mejores resultado.

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Conclusion
Declaration on Community Connectivity

The elaboration of the following Declaration has been facilitated by the IGF Dynamic Coalitioon on Community Connectivity (DC3). Inputs, comments and feedback have been provided by both DC3 members and non-members via the open mailing-list of the DC3 between July and November 2016.[132]

Preamble

Over four billion people may remain unconnected to the Internet, including around a billion who do not have access to basic telephony services.[133] Most people in rural and economically disadvantaged areas are unlikely to realise the benefits of connectivity in the near term. Rural communities and slums dwellers represent almost 60% of the worldwide population and, to date, traditional Internet access models have failed to provide coverage to such populations.

While Internet access has improved in several countries, concerns about vertical integration, breach of privacy and net neutrality have become increasingly concrete. Policy and regulation have been adopted to avoid abuses but regulatory environments may be cumbersome and ineffective in fostering connectivity.

To reverse these trends and reclaim the role of the commons in networks, it is necessary to create appropriate frameworks that empow-

132 This is the latest version of the Guadalajara Declaration, as of 4 November 2016. The Declaration may have been updated, due to the feedback received during the IGF 2016. See the DC3 open archives http://listas.altermundi.net/pipermail/dc3/ as well as http://www.intgovforum.org/multilingual/content/2016-dynamic-coalition-output-documents

133 See http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

er communities and local entrepreneurs to solve their own connectivity challenges, thus creating new opportunities in a sustainable fashion. Bottom-up strategies that embrace non-discriminatory treatment of Internet traffic and diversity in the first square mile can truly empower individuals and communities, allowing everyone to play an active role in making connectivity affordable and easily accessible.

1. Connectivity

Connectivity is the ability to reach all endpoints connected to the Internet without any form of restriction on the data-packets exchanged, enabling end-users to run any application and use any type of service via any device. Connectivity is the goal of the Internet.

2. Community Networks

Community networks are a subset of crowdsourced networks, structured to be open, free, and neutral. Such networks rely on the active participation of local communities in the design, development, deployment and management of the shared infrastructure as a common resource, owned by the community and operated in a democratic fashion. Community networks can be operationalised, wholly or partly, through local stakeholders, NGO's, private sector entities and/or public administrations and are characterised by the following points:

a) collective ownership: the network infrastructure is owned by the community where it is deployed;

b) social management: the network infrastructure is governed and operated by the community;

c) open design: the network implementation details are public and accessible to everyone;

d) open participation: anyone is allowed to extend the network, as long as they abide the network principles and design.

e) free peering and transit: community networks offer free peering agreements to every network offering reciprocity and allow their free peering partners free transit to destination networks with which they also have free peering agreements.

f) the consideration of security and privacy concerns while designing and operating the network

3. Community Network Participants

Community networks members have to be considered active participants and, as all Internet users, have to be considered both producers and consumers of content, applications and services. Notably community network participants:

a) have the freedom to use the network for any purpose as long as they do not harm the operation of the network itself, the rights of other participants, or the principles of neutrality that allow contents and services to flow without deliberate interference;

b) have the right to understand the network and its components, and to share knowledge of its mechanisms and principles;

c) have the right to offer services and content to the network, while establishing their own terms;

d) have the right to join the network, and the obligation to extend this set of rights to anyone according to these same terms.

4. Policy Affecting Connectivity and Community Networks

National as well as international policy should facilitate the development of connectivity and the deployment of community networks. Notably, national as well as international policy should:

a) be designed considering the impact on connectivity, with particular regard to individuals' human rights to freedom of expression and privacy;

b) lower barriers that may hinder individuals' and communities capability to create connectivity;

c) allow the exploitation of existing unlicensed spectrum bands or dynamically asigned secondary use of spectrum for public-interest purposes and consider the growth of unlicensed spectrum bands and special licenses for the needs of community connectivity.

d) incentivize the development and adoption of technologies based on open standards, free software and open hardware, which improve the replicability and resilience of community networks.

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Over four billion people are currently unconnected to the Internet, including around a billion individuals who do not have access to basic telephony services. The IGF Dynamic Coalition on Community Connectivity (DC3) promotes sustainable connectivity, fostering the role of the commons in networks and the elaboration of appropriate frameworks to empower communities and individuals through connectivity.

Community networks are a subset of crowdsourced networks, structured to be open, free, and neutral. Such networks rely on the active participation of local communities in the design, development, deployment and management of the shared infrastructure as a common.

This Report explores several dimensions of the community network debate. The Report and the Declaration on Community Connectivity are the official outcomes produced by the DC3 in 2016. The Report includes a selection of analyses of different community connectivity issues. Submissions have been evaluated for their novelty and undertook a blind peer-review process. The Declaration on Community Connectivity is included in this Report, as a conclusion.

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