Horizon 2020

Project title: Network Infrastructure as Commons

Incentives for Participation and Active Collaboration in CNs

Deliverable number: D2.3

Version 1.0

Co-Funded by the Horizon 2020 programme of the European Union
Grant Number 688768

Project Acronym: netCommons
Project Full Title: Network Infrastructure as Commons.
Call: H2020-ICT-2015
Topic: ICT-10-2015
Type of Action: RIA
Grant Number: 688768
Project URL: http://netcommons.eu

Editor:	Panagiota Micholia, AUEB
Deliverable nature:	Report (R)
Dissemination level:	Public (PU)
Contractual Delivery Date:	December 31, 2016
Actual Delivery Date	February 24, 2017
Number of pages:	50
Keywords:	community networks, monetary incentives, socio-psychological incentives, stakeholder participation, active contribution, resource sharing, incentive mechanisms
Authors:	Panayotis Antoniadis, Nethood Merkouris Karaliopoulos, AUEB George Klissiaris, AUEB Iordanis Koutsopoulos, AUEB Panagiota Micholia, AUEB
Peer review:	Leonardo Maccari, UniTn

Executive summary

Community networks across Europe and worldwide compose an extremely colorful picture with respect to both the societal dimensions they embody and their organizational structures. These two aspects of Community Networks (CNs) were analyzed in the netCommons deliverables D1.2 and D2.2, respectively. Equally versatile are the roles and incentives of their stakeholders, *i.e.*, of all those entities (users, volunteers, public administration bodies and private companies) that contribute to these complex socio-technical ecosystems one way or another. This first edition of the netCommons deliverable on "Incentives for Participation and Active Collaboration in CNs" aims to systematically survey, analyze, and classify the variety of incentives that motivate the participation of different stakeholders in a CN.

To this end, we first explicate in section 1 who these stakeholders are and the different dimensions CNs bear as socio-technical entities, drawing on the work reported in D1.2 and D2.2, respectively. In this same introductory section, we also distinguish between *intrinsic incentives of stakeholders*, *i.e.*, intrinsic motives that encourage participation in CNs, against *extrinsic incentive mechanisms* that are put in place to further encourage such participation. Finally, for end users, we identify different modes and levels of participation, ranging from the "free rider" to the "power user" type.

We then proceed in section 2 with a presentation and discussion of incentives *per CN stakeholder* (users, volunteers, professionals, and public authorities). For each stakeholder group, we distinguish between incentives of economic, socio-cultural, and political nature and provide examples of their expression in specific CN instances. Our work in this section draws on: (a) an exhaustive survey of papers and reports that have appeared in the scientific literature on this matter over the last decade; (b) questionnaires and structured interviews with leading figures of various CNs that we carried out in the context of netCommons; and (c) accumulated experience within the project out of our interaction with specific community networks (*e.g.*, Sarantaporo.gr, guifi.net, ninux.org).

Section 3 focuses on incentive mechanisms. It reviews mechanisms that are actually realized in existing CNs but also others that have been proposed in literature, without necessarily being applied to a specific CN. In the second case, it expands on mechanisms that have been proposed for other collaborative systems that present strong similarities with CNs in terms of organizational structure and distributed operation principles such as the wireless ad hoc networks, peer-to-peer systems, and online virtual communities.

In section 4, we pick up two CN instances, guifi.net and Sarantaporo.gr, as case studies for the detailed analysis that will follow in Y2 of the project. We explain why these two are chosen and present their detailed anatomy in terms of stakeholders, their incentives and the mechanisms put in place by the CN volunteer groups to ensure participation in the CNs.

We conclude in section 5 with a preview of ongoing research work on the analysis of the incentive mechanisms in these two CNs, which will escalate during Y2 of the project and will be reported in the follow-up edition of this deliverable (netCommons deliverable D2.8).

The current deliverable reports on the research conducted in the context of Task 2.2 of the netCommons project during the first year of its lifetime. This research takes inputs from D1.2 (organizational structure of CNs, stakeholders and roles) and D2.2 (different aspects of sustainability in CNs). In turn, it motivates and sets a solid background for: the follow-up work in Task 2.2, which will be reported in D2.8 (on the design and analysis of incentive mechanisms for CNs); the work in Task 2.3 on economic sustainability and alternative currencies, reported in D2.4 and D2.6 (alternative currencies as a participation incentive mechanism for CNs); but also the work on applications in WP3 (native applications as incentives for participation in CNs).

Contents

List of Figures

List of Tables

List of Acronyms

AP	Access Point
AWMN	Athens Wireless Metropolitan Network
B4RN	Broadband for Rural North
CN	Community Network
CONFINE	Community Networks Testbed for the Future Internet
CPR	Common Pool Resources
CPU	Central Processing Unit
CRM	Customer Relationship Management
DIY	Do It Yourself
DNS	Domain Name System
ERP	Enterprise Resource Planning
EU	European Union
FAQ	Frequently Asked Questions
FDN	French Data Network
FFDN	French Data Network Federation
FTP	File Transfer Protocol
GRNET	Greek Research and Education Network
GUADEC	GNOME Users And Developers European Conference
ICT	Information and Communications Technology
IP	Internet Protocol
ISP	Internet Service Provider
IT	Information Technology
LDAP	Lightweight Directory Access Protocol
MANET	Mobile Ad Hoc Network
NPO	Non-Profit Organization
NTP	Network Time Protocol
P2P	Peer to Peer
P2PWNC	Peer to Peer Wireless Network Confederation
RnD	Research and Development
SAX	Salut, Amor i Xarxa
VOIP	Voice Over Internet Protocol
VPN	Virtual Private Network
WCL	Wireless Commons License
WLAN	Wireless Local Area Network

1 CN stakeholder types and incentives' categorization

Community Networks (CNs) present a notable variety in the way they are organized and the different entities (stakeholders) participating in their activities [1], [2]. They are complex socio-technical systems combining the technological infrastructure with the multiple social dimensions of human communities [3]. It comes, hence, as no surprise that the participation in these systems depends on an equally versatile number of factors that vary both across and within the different types of stakeholder groups.

In the remainder of this section, we first review the different types of stakeholders that are involved in the CNs, as these were identified in D1.2 [1]. Then, we distinguish between different categories of incentives reflecting the different dimensions CNs bear as human communities, as described in D2.1 [3]. Both these taxonomies are key to the way the review of participation incentives is structured in subsequent sections. Finally, we explicate important terms that are repeatedly used in the rest of the report.

1.1 CN stakeholders

The four types of stakeholders met in CNs are distinguished and described in detail in [1] and [2], based on their roles, status, rights and obligations.

We summarize this taxonomy in what follows for ease of reference.

Volunteers: Volunteers are the initiators of the CN project. Their interests reside in aspects of *"neutrality, privacy, independence, creativity, innovation, Do It Yourselfs (DIYs), or protection of consumers' rights"*. They refer to the core teams that took the initiative to create the CN and are responsible for the management and operation of the network. It is not uncommon for volunteers to create a legal entity to manage the network and represent it to third parties (i.e., government, third party organizations, companies, Internet Service Providers (ISPs) providers). The key characteristic of the participation of volunteers in the CN is their lack of economic interest.

Users: Users are people that join the network for different kind of reasons. These reasons may refer to activism, privacy, acquiring connectivity, data exchange, communication, gaming or receiving qualitative services provided by the professionals. When users pay directly (connectivity fee) or indirectly (through consumption of professional services) fees to the CN, they are considered *customers*. Customers are practically users that are interested in *"network access and service consumption"*. They connect to the network and they can either forward traffic (backbone node) or consume it (client node).

Professionals: Professionals are interested in aspects such as *"demand, service supply, and stability of operation"*. They use the network to promote their expertise in a specific field. They bring qualitative services to the users of the network and get compensated for it. They contribute to the technical infrastructure directly (contributing actual hardware) or indirectly (contribute economically).

Public administrations: Public administrations are 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"*. They are third party entities that can contribute offering technical infrastructure to the network (unused fiber cables) or contribute in other ways. Their responsibilities involve regulatory matters regarding network operation. There are examples of public administrations that offer public space for hosting CN equipment, making agreements and contributing public equipment, contributing economically, validating licenses for interactions within the network and agreements for participating in it.

These stakeholder types are essentially a super set of the entities that are relevant across *all* CNs; namely, each CN possesses its own distinct subset of these categories. For instance, "Users" and "Volunteers" are intuitively present in all CNs. More rare is the direct involvement of public administrations in a CN initiative; and even rarer the participation of professionals.

1.2 Incentive categories

The categorization of incentives is based on the observation that CNs are Information and Communications Technologys (ICTs) systems [4] built and operated by humans. As such, they form a type of society [5], whose physical existence is based on technological elements, i.e., infrastructure, software. The societal hypostasis of community networks encompasses political, socio-cultural and economic dimensions [3], which are all inherently dependent on the social interactions among network participants. The technical infrastructure itself can be considered as a result of social interaction among network participants and as an *ex-ante* condition for further *political, socio-cultural and economic* interactions among the community members.

These three inherent dimensions of CNs are interdependent with each other and so are the incentives related to them. The way that a community network is governed (political dimension) influences the creation of services, applications, and distributed content (socio-cultural activities), as well as potential economic transactions and the creation of markets (economic activities). The provision of services within the network has the potential to influence the economy of the network. Hence, the incentives of network participants can be strengthened and enhanced or weakened and blocked depending on the rules upon which the network is managed (political dimension), the services and potentials it offers (socio-cultural dimension) and the economic benefits it generates (economic dimension).

1.2.1 Incentives related to the political dimension of CNs

Political reasons are often relevant to the participation of stakeholders in CNs, primarily for "Volunteers" and "Public administrations" but also "Users". In fact, many CNs have started out as initiatives of activists that wanted to try out an alternative to the commercial ISP networks, whereby the telecommunications network infrastructure is owned by the network participants. Higher autonomy, self-organization, cooperative management and participatory governance are original political purposes that found their expression in many of these networks. They are practiced in both the organizational structure, e.g., through participatory decision making procedures, and the operational rules of these networks.

These are often coupled with newer digital society moves in favor of net neutrality and ownership/control rights over personal data. Hence, users may be motivated to participate in CNs because they can freely circulate their data. This way, CNs satisfy their privacy needs and their dislike for

data discrimination practices applied in the Internet (net neutrality). In some cases (Athens Wireless Metropolitan Networks (AWMNs), Ninux, Freifunk), CNs have practically created parallel Internets with a rich offer of customized local services and applications resembling what Internet offers; the difference is that these apps store and manage data locally, without interfering with the public Internet.

Finally, bridging the digital divide in remote under-served areas has been another frequent motivation for building and supporting CNs. In these cases, CN initiatives make up for the lack of infrastructure investments by commercial network operators in areas where such investments are not considered economically attractive. Those bottom-up networks are primarily, if not exclusively, used for Internet access.

1.2.2 Incentives related to the socio-cultural dimension

The socio-cultural aspect refers to certain types of interactions and social effects that result from the involvement with the activities of a CN.

People may participate in a CN considering it as a way to spend their leisure time, socialize and make new acquaintances and, even, friendships. Common interests in new technologies and the desire to experiment with them often catalyzes the development of social relationships. Several CNs maintain an agenda of social events for their participants.

Likewise, quite often, participants view these networks as means to acquire new knowledge and exchange information on network/radio equipment, services and applications, and experiment with them. The high involvement of radio amateurs and technology enthusiasts in most CNs stands as evidence of such motives.

In either case, participants receive non-monetary rewards out of their involvement in the CN. Inner needs of relatedness, collective feeling, competition, but also of social recognition and acceptance, projection and acknowledgement of personal identities, satisfaction of their ego involvement and self-esteem can be satisfied when involved in actual or virtual communities. These types of socio-psychological motives are usually implicit and not easy to acknowledge but often emerge as important motivating factors for the participation in ICT communities in general and CNs in particular [6].

1.2.3 Incentives related to the economic dimension

Economic incentives are indeed relevant for the participation in many CNs. Several people among those who have led such initiatives openly argue that the capability to generate monetary value and the involvement of commercial entities are prerequisites for the long-term success of these networks [7]. The economic incentives mainly pertain to the stakeholder types of "Users" and "Professionals", in the rare instance (e.g., guifi.net) that such entities are part of the CN ecosystem.

"Users" often view these networks as ways to gain access to Internet at reduced cost, at the extreme case even for free. Further second-order benefits for users of these networks may come from crowd-powered practices i.e. getting compensated for performing any online or physical task announced by network users (answer online questionnaires, provide tutoring assistance, etc).

"Professionals", on the other hand, may benefit from the infrastructure deployed by these CNs to offer services to otherwise unreachable end users, without having to upfront invest huge amounts to offer Internet connectivity to them.

In the remaining of this Chapter we provide a thorough analysis on the incentives that urge people to participate in CNs and their inherently interconnected social dimensions.

1.3 Defining terms and concepts

1.3.1 Intrinsic vs. extrinsic motives

When referring to these factors, it is worth distinguishing between *intrinsic* and *extrinsic* motivation factors, even if the borderline between the two is sometimes vague.

Maybe the most ambitious effort to analyze these two types of motivation in the context of wireless CNs is the generic motivation and effort model in [6]. Therein, intrinsic and extrinsic motivation instances are analyzed and related to the CN participants. To this end, references are drawn on Self-Determination Theory [8], according to which being motivated is synonym of being *energized towards an activity*.

According to the proposed classification, intrinsic motives include the fun and challenge an activity incorporates as opposed to some external pressure or reward. Likewise, as intrinsic motivation counts the satisfaction of basic psychological needs such as *competence, autonomy and relatedness*. On the contrary, extrinsic motives refer to any kind of externally driven participation linked with the *expectation of explicit rewards or external pressure*, enhancement of *self-esteem and ego involvement* (receive credit by others), satisfaction of *personal needs for broadband connectivity and services*, enhancement of *human capital* and augmentation of *career prospects* as well as *altruistic and ideological aspirations*.

An intermediate category that could be viewed as an extension of intrinsic motivation and is called *Obligation-based Intrinsic Motivation* incorporates the notions of *collective identification* (sharing of common ideas and beliefs) and *reciprocity* (as the exchange between network members).

	Political	Socio-cultural	Economical
Intrinsic motives			
Autonomy	x	x	
Relatedness		x	
Competence		x	
Fun, Challenge		x	
Extrinsic motives			
Altruistic & ideological aspirations	x	x	
Monetary/virtual rewards			x
Self-esteem enhancement		x	
Ego involvement		x	
Need for broadband connectivity		x	x
Human capital & career prospects			x
Obligation-based intrinsic motives			
Reciprocity		x	
Collective identification	x	x	

Table 1.1: Incentives for participation in CNs.

The relation of the CN incentive categories, as described in Section 1.2, and the taxonomy followed in [6] is attempted in Table 1.1. Roughly, this taxonomy states that intrinsic motives have a strong cultural dimension and more rarely (in the case of autonomy) a political flavor. A similar mix of dimensions is met in the obligation-based motives, but now the social influence and dependence are more explicit.

On the other hand, the extrinsic motives encompass all three incentive categories, reflecting all the different ways that participating in the CN initiative can be "rewarding" for the actors. This broad range includes direct (monetary or virtual) or indirect (enhancement of career prospects, cheaper broadband Internet access) financial rewards, but also the satisfaction of ideological aspiration of political flavor.

1.3.2 Incentives and mechanisms

After providing a new taxonomy for the aforementioned incentives in the basis of CN dimensions, the report distinguishes between the implicit motives that were described in the previous section and mechanisms and tools that can be deployed to match these types of incentives.

Each one of the aforementioned motives possesses and expands among extrinsic and intrinsic motives describing in this way the pre-existing tendency of a person to participate in a community network. We use the term *incentive* and *motive* interchangeably to describe the implicit tendency towards an activity. The incarceration of the reasons to participate in a CN happens by devising *explicit mechanisms* and tools that build upon the pre-existing tendencies. The mechanisms can either be theoretical in terms of the devised model that have been proposed in the literature but have not been applied yet or actual implemented mechanisms and tools. In either case, in order to attain the existing participation motives, a set of mechanisms and tools are presented in Chapter 3.

1.3.3 Engagement vs. sustained contribution

The participation of people in a CN is a term with multiple aspects. It is quite clear that there is not one specific way to participate in a CN. When people are first acquainted with a CN, they come across the question: "Should I join the network or not?". If they decide to join the network and find the necessary equipment to do so, then the first engagement step has been done: i.e., a user device is set up and running as part of the network. The device could either be a node that contributes to the network by forwarding traffic or a client device that consumes traffic. Either way, participating in a CN with such a variety of dimensions (see Section 1.2 for details) can mean much more than just connecting a device to it.

There are various matters that play an important role in the survival of the network and active participation is required for addressing them. For example, the operation of the network is subject to experience technical problems and once it does, some of the members will have to deal with solving them. In other cases, some of the members of the network lack the technical expertise needed to use the network in its full potential. Members that possess the knowledge and are skilled enough can provide this information and train them. Hence, the provision of services, development of the network, implementation of tools, participation in meetings, collective decision making, crowd funding campaigns, technical assistance and so on, are issues that call for constant involvement with the network.

1.3.3.1 Participation levels

Taking on these responsibilities comes not only with benefits but with costs as well. Remaining active and contributing in the constantly evolving CN organism is not an easy engagement. Due to the aforementioned reasons, the participation in a CN comes in multiple levels, just like the CN itself. It is possible to define three distinct levels of participation:

- **Highly active:** contribute to app development, training, social events, collective activities, contribute to governance matters, dealing with operational problems, participate in the core team, produce content, devote personal time and efforts.
- **Active:** Contribute to the technical infrastructure i.e. set up a node, route traffic, have the node always on, contribute to the network economically directly or indirectly.
- **Passive:** Posses simple client nodes that consume traffic, use the network for its services, does not contribute in any other way.

Highly active and active contributors are considered crucial for the sustained operation and development of the CN. On the contrary, passive users extend the network numerically but do not necessarily contribute to its viability. The survival of each CN can be connected to the number of users in each of the aforementioned categories. For example, if the passive users of the CN are for a long time the majority of users in the network, the network is bound to decay. Transition among these levels of contribution is also of great importance.

1.3.3.2 Participation fatigue

Experience, in particular with online virtual communities, dictates that it is not unusual for people to engage in a community and then gradually lose interest in it. This behavioral trend is so frequently reported that a special term, *participation fatigue*, has been devised to denote it.

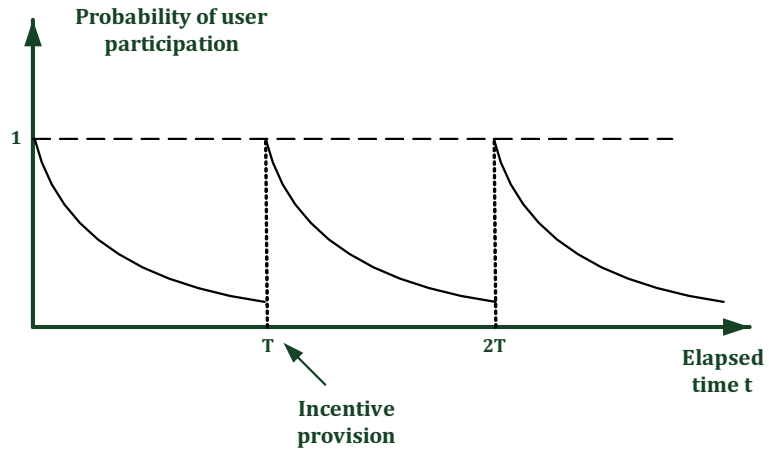

Figure 1.1: Participation fatigue with the time elapsed among incentive provision.

The implications of the phenomenon for the participation in a CN are two-fold. First, it implies that the intrinsic motivation for participation in a CN is a dynamic process that may change over time. This is mainly the case with end users who like experimenting with new stuff and learn about new technologies, or volunteers that may find that some of their political causes are not shared by other participants.

Secondly, and as a consequence of the first implication, proper incentive mechanisms should cater for this time effect. Namely, beyond *what* will be offered as incentive to CN users, they might also need to address (every) *when* should this be provided.

Schematically, this interaction between the participation fatigue and the incentive provision is depicted in Fig. 1.1. The provision of incentives should push the user's interest in the network high at moments when this has declined significantly and does not necessarily come at constant intervals as

simplified in the figure. Indeed, incentives coming at the wrong time (too early, with interest still very high, or too late when the interest is lost entirely) might be a waste of resources and effort.

2 Stakeholders' incentives for participation in CNs

In this Chapter, we analyze the possible incentives distinguishing them per stakeholder type. Figure 2.1 summarizes the main type of incentives that we have fond suitable for the four main categories of stakeholders as defined in Chapter 1.

The main inputs we have used to build the analysis and description in this Chapter:

- Broad studies of community network participants focusing on specific CNs: [9, 10, 11, 12, 13];
- A couple of surveys about CNs carried out in the context of earlier research activities outside the project [14];
- Questionnaires, interviews, and studies that have been carried out in the context of the netCommons project: [1, 3, 7, 15].

The emphasis is on what is *actually* reported to be serving as incentive for participation in existing CNs. Later, in Chapter 3, we review incentive mechanisms, i.e., extrinsic measures that have been proposed for these networks to further motivate participation in the CNs.

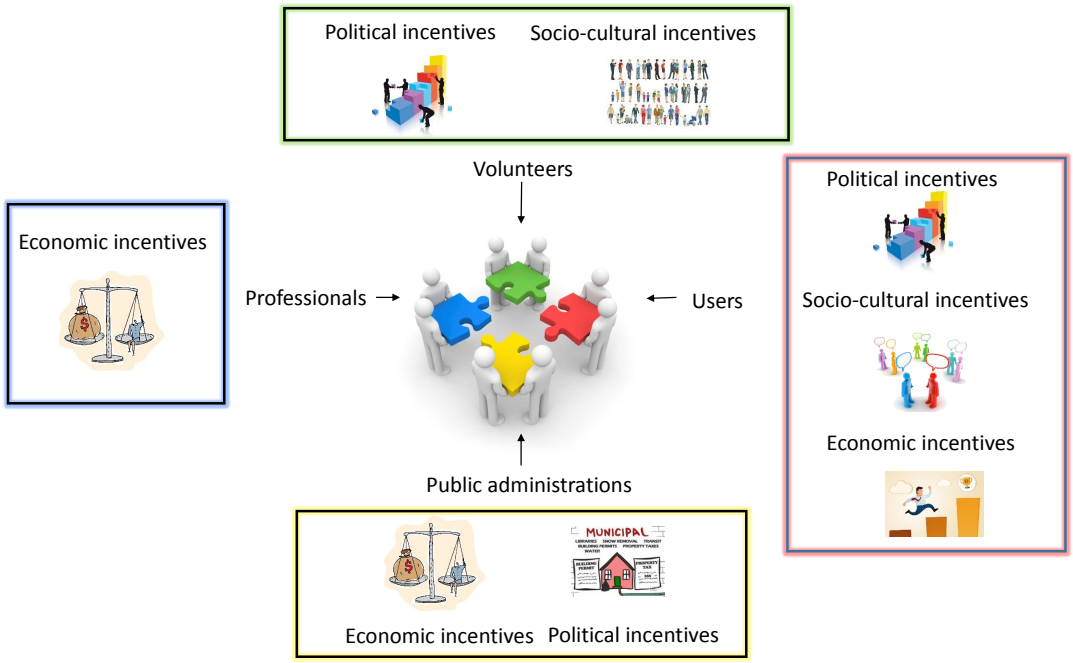

Figure 2.1: Primary participation incentives per stakeholder type.

2.1 Incentives for volunteers.

The volunteers, as defined in deliverable D1.2 [1], form one of the two stakeholder groups that are relevant to each and every CN. The term points to the small group of people who play a leading role in designing, planning, and deploying the network [16]. Typically, this is the group of people that first

sets up network nodes and interconnect with each other to form the first network instance. Almost always, (a subset of) these people retain their interest in the network after its original deployment phase, holding the responsibility for the operation and maintenance of the CN [17]. And more often than not, they take an active role in the network expansion, either through helping with the technical matters and/or organizing informational and training events for potential participants.

The volunteer groups usually comprise people that cumulatively possess knowledge and expertise over a wide set of areas [18]:

- In technical matters concerning the development of a computer network, ranging from installing and fine tuning antennas to configuring connections, Internet Protocols (IPs) addresses and network routes, and troubleshooting problems at both hardware and software level;
- In legal matters such as national and international legislation around technology and civil law, including the provisions of licenses, regulation status, and possible agreement frameworks for the operation of the network;
- In potential sources of funding, primarily from public administrations at national and European Union level.

They usually create nonprofit organizations to acquire status of legal entities. This lets them have a voice and interface with third parties on legal and regulatory matters, but also get involved in financial transactions (e.g., user subscriptions, fund raising, purchase of equipment).

The volunteer groups typically involve technology enthusiasts, radio amateurs, hackers, activists, and academics. Their motives have a strong bias towards political and socio-cultural values and ideals, which is not met in any of the other three stakeholder groups. Experimentation with technology, open software and do-it-yourself (DIY) tools, sensitivity to privacy and network neutrality, the desire to bridge the digital divide, but also commitment to the community spirit and social movement, participatory governance and decision-making, and protection of consumers' rights, count as primary motives of people that lead the CN initiatives, mixing in variable ways both across and within the different CNs. Economic incentives are also present in a few cases, albeit to a smaller extent. On the contrary, in many cases, the members of the volunteers' group end up investing a lot of personal effort, time, and money to the CN initiative, without direct financial return of any kind.

A final note worth making is that the incentives of the volunteer groups are not necessarily static throughout the lifetime of the CN initiatives. There are instances where these have evolved over time, adapting to the group membership (*e.g.*, members joining or leaving the group), new technologies that were made available over time, and the evolution of the surrounding legal/regulatory environment.

2.1.1 Political incentives

Political causes often serve as driving forces for the groups that lead CN initiatives. A characteristic example of principles underlying such initiatives is found in the declaration by the guifi.net foundation, the volunteers' group that has developed and still operates the guifi CN, in Catalunia, Spain [19, 20, 21]:

- Freedom to use the network, as long the other users, the contents, and the network itself are respected.
- Freedom to learn the working details of network elements and the network as a whole.
- Freedom to disseminate the knowledge and the spirit of the network.
- Freedom to offer services and contents.

Such causes often prove to be strong enough to fuel these groups' active involvement with the CN despite the effort, time and money this requires and the fatigue phenomena described in Section 1.3.3.2. We list the most important of such causes in what follows.

2.1.1.1 Bridging the digital divide

CNs have thrived in rural areas where the access to the Internet, and ICT services more generally, was (and, in many cases, still is) poor or non existent. The main reason for this is the reluctance of commercial operators to invest on fixed broadband infrastructure in remote, sparsely populated areas, because they do not deem this cost-efficient. Internet connectivity alternatives based on wireless technologies (satellite Internet, cellular data), when they are available, are usually either expensive and/or of lower quality.

The right to (broadband) connectivity is a matter of equal opportunities in the contemporary digital society; and digital illiteracy puts at disadvantage populations deprived of it. The launch of CN initiatives has many times been the response to this threat. Interestingly, the volunteers' group is not always formed by local residents suffering the digital divide (as the case is with the Broadband for Rural Norths (B4RNs) [7] and guifi networks [1]), but also visitors or people with origins from the area under question, as the case is with the i4Free and Sarantaporo.gr networks, respectively. More analytically:

- **guifi.net** started in Osona, a village in Catalunia, in 2004. A group of people decided to create a network that would serve remote rural areas. Internet connection through conventional ISPs was not available due to the high cost related to the network deployment. The locals then, decided to solve the problem themselves by creating a wireless network throughout the region.
- **Sarantaporo.gr**. People with origins from the area of Sarantaporo in north-western Greece, and residents of Athens and abroad, originally wanted to create a website for the village. Yet, to their surprise, they realized that there was no network connection other than telephone modems and cellular data. This led a small group of people to put efforts and build a wireless community network. With the help of the Greek Foundation for open-source Software and local academic institutions, as well as funding from European Unions (EUs) Research and Developments (RnDs) projects, the network grew over time to cover currently 14 villages in the broader area and get used by much of the local population.
- **i4Free**[1][2]. This is a network that started from the initiative of a German engineer and professor in an island of Greece with poor Internet connectivity. Anticipating the importance of Internet resources and equipped with technical knowledge, the initiator of i4free created a small network at his own expenses so that locals could have access to ICT services.
- **B4RN**. The Broadband For Rural North (B4RN) initiative in Lancashire, UK, started in December 2011 by a local volunteer group led by a networking expert, Barry Forde. Contrary to other CNs, their CN is based exclusively on fiber and was developed as a more affordable and cost-efficient alternative to broadband access than alternative technologies such as satellite and cellular.

For all these cited CNs netCommons Deliverable D1.2 [1] and D2.2 [7] report details and analysis on their structure and motivations.

[1] https://openhardware.ellak.gr/tag/i4free-gr/
[2] https://www.facebook.com/i4free.gr/

2.1.1.2 Openness, net neutrality, and privacy of personal data

These highly controversial subjects have served as primary motivations for CN initiatives. The principle of net neutrality dictates that traffic within the network should be treated in an equal manner independently of the content or the source. The data that is communicated across the network is not subject to discrimination. However, this is not the case in the internet where large ISPs are able to block and prioritize traffic without having the consensus to do so [22, 23, 24], often also disregarding basic legislation on freedom of communications.

Moreover, volunteers are often interested in accessing ICT services without having to compromise their **privacy**. This applies for technology enthusiasts, activists and users in general that wish to protect their private content.

CNs such as the French French Data Network Federations (FFDNs) and the German Freifunk declare privacy/anonymity and net neutrality as integral parts of their manifesto and incorporate them in their fundamental operation principles.

- The **FFDN**[3] was founded in 2011 as an umbrella organization embracing 28 CNs operating across France (plus one in Brussels, Belgium), including the most popular French CN by that time, French Data Networks (FDNs). This happened after a a call by FDN's president Benjamin Bayart and other FDN active volunteers to people across France to start building their CNs. This call came as a response to several events that made an impact on the debate about digital rights (*e.g.*, WikiLeaks, Cablegate,DataGate). All CNs under the FFDN association adhere to values of collaboration, openness and support of human rights (freedom of expression, privacy) embedded by the Free Software Movement.
- **Freifunk** is an open initiative that supports free computer networks in the German region, counting about 150 local communities with more than 35,000 access points. It started its operation in Berlin attracting many artists, activists and tech enthusiasts from all over Europe. The incentives behind its initiative are reflected in the very early statement of its basic principles of operation: (a) Public and anonymous access; (b) Lack of commercial flavor and censorship; (c) Decentralized operation and community ownership over it.

2.1.1.3 Autonomy, self-organization and alternative communication models

These are common motives for the original deployment and subsequent operation of CNs [9], especially in urban areas, where the digital divide threat is much less pronounced. Community networks such as Consume[4][5] and Free2Air[6][7] started out representing alternative approaches to the commercial Internet provision, aiming at higher freedom and control over personal communications. In other cases, such as guifi.net, which started as an attempt to bridge the digital divide, such political purposes emerged as an equally strong motivation factor, especially when the number of network connectivity alternatives increased. In more detail:

- **Consume.** This CN was one of the first ones to be conceived and deployed in Europe. Its development was led by James Stevens and Julian Priest and a number of people that were organized around them. Although the original motivation was to save Internet access fees for

[3] https://www.ffdn.org/.
[4] http://consume.net/
[5] http://wiki.p2pfoundation.net/Consume
[6] http://www.free2air.org/
[7] http://wiki.p2pfoundation.net/Free2Air

conducting business (see Section 2.1.3), the initiative evolved to an attempt to "short-circuit" what, by that time, has become the *"anti-competitive telecommunications market model"* [7].

- **Free2Air.** This initiative was initiated in East London as an alternative network to the commercial Internet provision. The initiative was run by a small number of artists and a number of other individuals, a central figure being Adam Burns, an Information Technologys (ITs) security expert. Himself together with a few others set up the network addressing the main technical tasks such as network routing, planning, and other tasks. Burns describes Free2Air as a largely political project, attempting to put into practice ideas about control and ownership of personal communication. He recalls that the one of the two main motivations for starting the network was exactly to try de-mediating the personal communication and getting more control over the communication needs [7]. Burns himself was involved in significant political activities participating in debates on the idea of commons and what this implies for governance, legal and policy issues, but also the alternative organization and autonomy of communication.
- **guifi.net.** Guifi CN has formalized its alternative approach to network operation and management in the context of the economic theory of Commons. The guifi.net foundation promotes the view of their CN as Common Pool Resourcess (CPRs) and apply principles of CPR management, as set by the Nobelist economist Elinor Ostrom [25], to their CN management.

2.1.2 Socio-cultural incentives

Socio-cultural motives are strongly relevant to the participation of volunteer groups in CN initiatives. There are instances that such motives stand behind the original conception and deployment of CNs; in other cases, these may emerge in a later stage across the people who run and manage the CN.

Concepts of intrinsic motivation such as **creativity, innovation**, enjoyment are found in the group of volunteers in CNs. Education and knowledge acquired from the interaction with other network members and involvement with the network [11], tend to be noted and appreciated by the members of a CN.

2.1.2.1 Experimentation with technology, hacking and do-it-yourself culture

Several initiatives are driven by hackers, technology enthusiasts, and academics who enjoy experimenting with network and radio technologies. The involvement within such a community presents them with a unique opportunity to further enhance their technical knowledge and practise it over real networks.

- **AWMN.** The Athens Wireless Metropolitan Network (AWMN) was founded in 2002 by a group of people involving primarily network technicians and enthusiasts and radio amateurs. The network was characterized by a culture of experimentation and improvisation [7]. For the people leading the activity, it was a great place to test and enhance their knowledge and create things. This involved the manufacturing of antennae, the production of feeders, and the design of mesh protocols for routing traffic over the network.

  This experimentation and hacking culture is best reflected in the unparalleled offer of applications and services that were developed for AWMN, *i.e.*, to work as native services without need for public Internet connectivity, including games, libraries, network monitoring tools, Domain Name Systems (DNSs) solutions, and experimental platforms.
- **Ninux.** Experimentation and hacking were the primary motivation behind setting up the Ninux CN in Italy early 2000s. This is directly reflected in its name, as "Ninux" stands for "No

Internet, Network Under eXperiment". As with AWMN, Internet access is not officially offered by Ninux, which operates as an experimental platform for decentralized protocols, policies and technologies.

- **Funkfeuer.** Funkfeuer is a free experimental wireless network across Austria. It was built and currently maintained by a group of computer enthusiasts with different motivation and interests. Funkfeuer is committed to the idea of DIY.

2.1.2.2 Community spirit and altruism

Altruism, often coupled with belief in community ideals emerge as important motivations for the active involvement of volunteers' groups in CNs.

- **B4RN.** The community ideals are highly prioritized in B4RN. The volunteer group has been set up to operate as a community benefit society which "can never be bought by a commercial operator and its profits can only be distributed to the community." This was a decision early made by the few people who initiated the CN.
- **Sarantaporo.gr.** The Sarantaporo.gr involves people who are activists in the area of commons and supporters of community ideals. They place a lot of emphasis on cultivating these ideals in the residents of the area with parallel activities and social events. Even the small yearly subscriptions that aim at the maintenance of the network infrastructure are determined at village/community rather than individual level.
- **i4Free.** The leading figure behind the i4Free CN in Greece, is also a warm fan of community life and ideals. He has spent enormous amounts of time in training and educational events trying to build a community around the CN, even without much success as he admits [7].

Altruism and the spirit of community are also evidenced in other CNs, where the primary motivation of volunteers is the experimentation and hacking culture or other political reasons (see Section 2.1.1). Therefore, in AWMN and Ninux, guides and instructions have been developed with the certain purpose of providing information and recommendations to interested potential participants in order to buy and set up their own node.

2.1.3 Economic incentives

Economic incentives are rarely relevant to the volunteers' group. These groups are mostly organized as nonprofit organizations and, in several cases, their members end up funding the initiative one way or another. Yet, there are some instances that such incentives are present, or were present at some stage of the CN development. In all cases, the underlying idea, when present, is how to save money with CNs compared to commercial alternatives rather than how to make money out of the CN initiative.

- **Consume.** One such case is the Consume network, one of the very first CN initiatives that set a recipe for other CNs across Europe. James Stevens ran a technology incubation business offering web, live streaming and video distribution services through a leased optic fiber connection. He came up with the idea to connect buildings through wireless mesh links as a way to bypass the expensive licence costs and regulatory constraints related to expanding the fiber communication across the buildings.

  Yet, the initiative soon acquired more political purposes, as a movement against anti-competitive practices that protected certain financial monopolistic interests in UK. And the two people that

led the development of the network, Stevens and Julian Priest, ended up undertaking almost the full financial cost related to the network deployment.

- **BARN.** In the case many CN initiatives that aimed at bridging the digital divide, such as the B4RN initiative, the CN was developed as a more affordable and cost-efficient alternative to broadband access than alternative technologies such as satellite and cellular. Typically, in the rural areas under question there is no fixed commercial broadband infrastructure since commercial operators do not consider it worth in financial terms. Yet, there are other options such as satellite or cellular that are typically more expensive and of lower quality. Many of these CNs offer better connections at more affordable prices than the competing solutions.
- **Ninux.** Indirect economic benefits can come through the enhancement of an individuals human capital. From their involvement with the network, individuals in Ninux have acquired knowledge needed to find jobs in the ICT sector.

2.2 Incentives for users.

Compared to the volunteers' groups, the CN users exhibit far higher variance with respect to their participation levels and motivation.

They may be *highly active* and participate in the events organized by volunteers or other types of collective activities, provide technical experience, develop apps, and devote personal time and efforts to the network; or they may simply have set up a node without contributing personally to the activities of the community; or they may use the CN to get Internet access or access to local services without contributing in any way (economic, hardware or personal efforts). This type of users are termed *free riders*. Their participation may benefit the network in terms of the network effect i.e. the larger the network the easier to enter, so even a passive users such as free riders can potentially enable others to join.

Likewise variable is their motivation for joining the CN. Decisive for many of them is the expectation of cheap, or even free, Internet access. For others, the CN is viewed as a perfect opportunity to acquire new knowledge and experiment with high tech stuff. Socializing and becoming part of a bigger community is also reported as important motivation for participation in the CN. Finally, political causes are also evidenced as motives for user participation, albeit to a smaller extent than in volunteer groups.

2.2.1 Political incentives

Although users of the network are not involved in its initial deployment and operation, they may too experience political motives for participating in the network.

Many CNs as seen in Section 2.1.1 have been created under aspirations of privacy and net neutrality, autonomy and self-organization, providing an alternative to existing communication models and bridging the digital divide in rural, poorly served by ICT operators, areas. The ideals underlying the initial development of these CNs are often passed on some of their members –the larger the CN the harder to find political causes uniting the whole community behind them.

2.2.1.1 Openness, net neutrality and privacy of personal data

Users often participate in CN initiatives in an attempt to get away with privacy concerns and tracking/monitoring software used in the public Internet. The aspects of privacy and neutrality have a strong role in networks that utilize the Picopeering agreement[8] and are part of the movement for open wireless radio networks[9]. The Picopeering agreement is a baseline template that formalizes the interaction between two peers of the network. Its basic properties include:

- Node owners agree on free exchange of data into, out of or across a network without any interference.
- Node owners agree on providence of open communication by publishing relevant peering information subject to free license and information of contact.
- There are no guarantees of service level.
- Node owners can formulate use policies as long as they do not interfere with the basic parts of the picopeering agreement.
- Local amendments can take place by the will of node owners.

2.2.1.2 Autonomy and self-organization

The participation in CN groups cultivates feelings of autonomy and self-organization. Self organization is also depicted in the way that new users connect to the network, where they have to rely on their own resources and on the voluntary assistance of experienced network members.

Being part of an independent network satisfies personal ideology aspirations for self-organized network and autonomous use. The ability to participate in collective decision making and contribute to the a "common" network infrastructure following an alternate model of ICT access is itself an experience for users interested in participating in a community of "commons". In the study found in [9], 94.5% responded that they experienced autonomy in their groups and expressed freely their own opinions.

2.2.2 Socio-cultural incentives

A CN is a characteristic example of participatory involvement, where users dedicate their efforts and time to the network [26]. A number of services and applications combined with other activities that one way or another revolve around the CN, offer users the opportunity to communicate, educate and entertain themselves, thus further motivating their participation in the network [27] [28].

2.2.2.1 Desire to experiment and acquire new knowledge on ICT

Technology enthusiasts participate in the network for experimenting with the technology and new gadgets. They find in a CN an as realistic as possible testbed for trying software they develop and hacked code, make network speed measurements, play with network mapping and management tools.

Other users view CNs as a "place", where they can acquire new skills about computer and network use. They are willing to invest personal effort on this but, at the same time, they expect to get triggers and help and guidance from the experts that know more about this. AWMN, Ninux, and Freifunk

[8] http://www.picopeer.net/PPA-en.shtml
[9] https://openwireless.org/

are CNs built by people with solid technical background and technology lovers. It is no surprise that many of the users these CNs attract tend to share similar interests.

In CNs that were initiated by volunteers with technical background, the amount and type of services, applications and self-produced software increased greatly within the community. In such CNs, users with these kind of motives appreciate getting access to:

- communication services with Voice Over Internet Protocols (VOIPs) and forums, mails, instant messaging,
- data exchange services with servers, community clouds, file sharing systems,
- entertainment services with games, applications, video and audio broadcasting,
- information and educating services with online seminars, e-learning platforms, wikis, monitoring tools, search engines.

In a study found in [9], 78% of the people that filled in questionnaires reported that the CN satisfied their personal needs, and 87% were identified as technology enthusiasts.

2.2.2.2 Social interaction

The smooth operation and development of a CN demands cooperation links at the network infrastructure level but also at the social level. Works [10] and [29] state that the social layer in Peer to Peers (P2Ps) systems is often neglected and left out of the design of incentive mechanisms. As social incentives count socially-aware mechanisms that may relate to concepts such as visibility, acknowledgment, social approval, individual privileges and status. This social activity is applied within the networks' technical limits [30].

Social motives are common in the participation of users and affect network growth and operation [31, 11]. In CNs, participants are able to share their ideas and interests, participate in groups, interact and communicate with other network members just like they would in any other online or physical community. Communication within or outside the network is an easily observable motive and one of the most popular reasons why users take part in online communities. Social networking and communication tools raise great interest and remain active even when other tools and services have a drop in their utilization. Finally, the ability to compete with other people and satisfy one's self esteem through the involvement in the community, or receive a certain type of credit by others in the community, are motives not as easy to distinguish but still present in reported studies.

- In the study in [9] results showed that 91.2% enjoyed interacting with the community, 88% felt that their efforts would be returned by other community members and 80.5% expressed that the community allowed them to work with people that they could trust and share similar interests.
- A socio-technical study in the rural area of northern Thailand, showed that when the network users had access to the Internet, messaging, email, online social networks, and online gaming where the services that received the greatest interest [32]. The social activity among the users exhibited a high degree of locality, which means that people used Internet to interact with people within the same CN.
- Similar results were found in a study of Internet service in a rural village in Zambia [33]. The implication is that local relationships can be of great importance in a CN [34] and that even though Internet service is dominant in certain community networks [35], if similar services could be applied at a local scale, they would have the potential to make an impact on CN users.

2.2.3 Economic incentives

Motives of economic nature are evidenced and have been reported in literature among CN users. Namely, users expect benefits of economic nature from their participation in the network, which may be direct or indirect.

2.2.3.1 Direct economic benefits

One of the main reasons why users join CNs is that they can get Internet access at lower cost than alternative commercial solutions, offered by telecom operators.

- **Sarantaporo.gr** offers Internet connectivity at a small subscription fee that is charged on per village basis. The resulting cost per network user goes down with the number of people sharing the Internet access and is several times smaller than what the same users would need to pay if they individually subscribed to available commercial solutions. In fact, the anticipation of the CN as "Internet for free" has put a lot of obstacles towards a a more participatory stance in sharing the CN operational expenses.
- **AWMN** members of the Association pay a typical small subscription fee in exchange for rights and involvement in decision-making processes. Non-members of the Association are not required to pay any kind of fee except for the expenses of their own equipment.
- One of the strong points in the evolution of **B4RN** has been its capability to offer fiber connectivity and Internet speeds at much more favorable prices than alternative commercial solutions did. Part of these savings relates to partly crowdsourcing the cost and effort for digging, which is a strong indication of how these initiatives can mobilize local skills and resources.

2.2.3.2 Indirect economic benefits

Users do not always identify economic benefits (only) with the capability to save money for Internet access.

- In **Sarantaporo.gr** young people (in the age of 18-35) view the CN as a path to information about job and further education opportunities; farmers search better markets for their products and cheaper suppliers for raw materials; and locals running coffee shops or taverns join the network in the anticipation that visitors appreciate the Internet connectivity feature when choosing where to go.
- In **AWMN** people out of those who contributed to its development also developed some business activity around the CN. They had Wi-Fi expertise and broader technical knowledge and opened shops to provide infrastructure for the network [7].

2.3 Incentives for professionals

The professionals is the stakeholder type that is most rarely met as a stakeholder type in CN initiatives. In fact, and to the best of our knowledge, guifi.net has been the first and single CN instance with clear and well articulated provisions for the involvement of professionals in the CN [36].

The term professionals points to companies, ISPs, small businesses, i.e., entities that use the network to provide commercial services. Such services may include Internet access, cloud storage, video streaming and video on-demand. At first glance, these entities do over the CN what they do over

any other network. However, the legal provisions and conditions of running business over the CN are different. In the case of the guifi CN, the guifi.net foundation prepares licences that serve the commons purposes and ensure that any professional entity providing service over the network will also contribute to the network expansion and maintenance [2].

The incentives for the participation of professionals in the network are primarily, if not exclusively, economic.

2.3.1 Economic incentives

Operating a CN technological infrastructure has certain costs. In most cases, participants that join the network by covering their own costs for the technical equipment needed to connect to the network. Apart of the costs for connecting to the network, participants are often required to pay a connection fee. User fees are not always enough to cover network operational and maintenance costs and extra funding needs to be guaranteed. Volunteers are the stakeholders responsible for seeking funding in order to cover the operation and maintenance costs of the network. Apart from public funding and donations they seek alternative ways to sustain the development of the network. To this purpose, the idea of creating a market within the network has gained ground.

- The most advanced network so far, is the **guifi.net** which incorporates a number of organizational rules to promote economic interaction within the network and motivate professionals to participate and offer their services using the CN technical infrastructure. Professionals are able to participate in the network, provide their services over it and get compensated for them.
- **B4RN**, a fiber community network located in Lancashire in England, employs a community funding model composed of shares for each investment, support for loans from the community and subscription fees for the participants. Community members can acquire B4RN shares. The network's expenses are covered by its own shareholders. B4RN utilizes a subscription model for both households and non domestic users. The subscription model is composed of a connectivity fee and different service fees for different types of users.

2.4 Incentives of public administrations

Public administrations may interact with a CN in different ways:

- by contributing to the deployment and growth of the CN through either funding the initiative or sponsoring network equipment.
- by positioning as a user of the CN services. In case of municipal authorities, they might let a CN manage and maintain equipment they own in return for network connectivity.
- as a regulating body facilitating or placing obstacles to its expansion and growth or by permitting the use of public space and resources by a CN (*e.g.*, as antenna or CN node installation sites)

It is possible to distinguish other types of groups that may get involved in the network such as Universities and other organizations. Depending on their level of participation they can sign collaboration agreements with the legal entity of the CN and contribute economic or infrastructure resources with or without compensation.

2.4.1 Political incentives

Public bodies may serve different political causes by participating in a CN and/or funding its activities.

First of all, it is possible to implement EU promoted policies against the digital divide and in favor of equal opportunities in the digital economy and society. CNs have shown over time their potential to mobilize local communities and altruistic forces in the society. They have managed to offer network connectivity in areas that are not attractive for commercial operators and might otherwise need generous public subsidies to cover.

Second, the CNs often strengthen the community links and raise awareness for issues concerning the local societies. Ideally, CNs sort of train users to become more engaged with the commons.

Third, on a more selfish and short-sighted note, local administrations (such as municipalities) can advertise the provision of network services as a political achievement that increases their chances of re-election.

- **Sarantaporo.gr** The Greek Foundation for open-source software, an initiative with the participation and support of the whole Greek academia, has sponsored the network equipment for the initial deployment of the CN in 2013. The University of Applied Sciences of Thessaly has provided them with connectivity to the Internet through its access to the Greek Research and Education Network (Greek Research and Education Networks (GRNETs)). Additional funds through the participation in the EU FP7 Community Networks Testbed for the Future Internets (CONFINEs) project allowed the network expansion to 14 villages in the area.
- **guifi.net** The local authorities of many villages in Catalunia have allowed the foundation to dig public space and lay down fiber for expanding the network coverage to these areas.

2.4.2 Economic incentives

Public administrations can participate in the network because this may prove profitable, just like professional entities do.

- **guifi.net** In the case of guifi.net public administrations can fund the network expansion through purchase of equipment in return for added value services over the network. In other words, they can invest in the network and get compensated for their investment.

3 Incentive mechanisms for CNs

?? described what may serve at the beginning as incentive for participation for different types of stakeholders, classifying them into incentives of political, socio-cultural, and economic nature. However, the original motives often do not suffice to ensure the participation of all stakeholders in the CN initiative. *Incentive mechanisms* have to be in place to further encourage and fuel these original motives, on the one hand, and prevent phenomena that might weaken the original motivation, on the other hand. Such phenomena include:

- **Free-riding and selfish behaviors** Free riding is a common problem in all distributed systems that are conditional on their users' contributions and users share the roles of both contributing and consuming resources from them. In CN initiatives, users need to contribute nodes, ensure that these nodes are on and serve traffic from the other nodes, and be willing to further connect to other nodes in their proximity. Yet, there are typically many users who are solely interested in enjoying network connectivity without themselves contributing resources. Such behaviors can easily lead to the depletion of network resources. If several users coordinate to implement unfair behaviors, i.e., they collude, the CN may quickly degrade and possibly disappear entirely.
- **Asymmetries in the effort devoted by CN participants** On the other extreme, in each CN initiative, there are users who devote asymmetrically high effort, time, and sometimes, material values (money, equipment) to the network purposes. Even for the most altruists of them (e.g., members of the volunteer groups), some mechanisms are required to ensure their sustained contributions.
- **Unclear legal status of CN initiatives** In several cases in the past, and in some cases even in the present, the legal framework of the CNs' operation has not been very clear. Doubts as to whether the CN is lawful tend to deter users from joining the network and participating in its activities.

In what follows, we present incentive mechanisms that are either in place in different CNs or have been proposed, without (yet) finding a path to implementation, in the literature. In this latter context, we also review mechanisms that have been proposed for *similar* systems such as wireless ad-hoc networks, P2Ps systems, and online virtual communities. These systems display inherent structural similarities with CNs in that they also depend on the collective effort and cooperation of their participants.

In wireless ad-hoc networks, any node can become a router and forward other nodes' data, and this is the same for CNs. The network existence per se is conditioned on the cooperation of different network users. The additional difficulty, when compared to CNs, is their dynamically changing topology due to the mobility of nodes. Most of these systems have self-organization and recovery mechanisms that let data find quickly alternative paths to their destination even when a node leaves the network and disrupts a path.

In P2P systems, peers have to share the resources with each other and, as with CNs, each node (peer) nominally serves as both a provider and a consumer of resources. Issues of net neutrality and resource sharing incentives among peers are equally relevant to P2P networks and CNs. The difference with CNs is that P2P sharing is possible across larger geographical areas, through overlay networks that may span across continents.

Finally, CNs resemble in many ways online virtual communities that form in social media sites. The similarities between the two types of communities concern their organization, the different levels of participation across their members, participation fatigue phenomena. What is missing in the online communities is the physical proximity and contact, as means to reinforce community links among members; however, in many cases, this is, at least partially, compensated by the existence of common interests and preferences among their members.

In what follows, we describe different incentive mechanisms aiming at motivating the participation in CNs. We group them into six main categories.

3.1 Enforcing fairness in users' contributions and interactions

Avoiding the phenomena of free riding and unequal effort sharing among CN participants should be one of the main concerns in the CN operation. Such phenomena may have a destructive impact on the CN and pose a direct threat to its long-term sustainability.

Unfortunately, with a few exceptions, rarely there are mechanisms in place in existing CNs to prevent such phenomena. This holds despite the quite broad range of solutions that have been proposed in the literature, either in the specific context of CNs or that of similar systems (P2P, wireless ad-hoc and online virtual communities) [37, 38].

3.1.1 Reciprocity-based mechanisms

Reciprocity is a broad term that incorporates the notion of human cooperation in different interaction scenarios [39]. *Direct* reciprocity keeps records of the interaction of two specific individuals so that the accounts are settled between those two. *Indirect* reciprocity does not consider two specific individuals but rather an asymmetric random exchange based on reputation scores of each individual.

3.1.1.1 Direct reciprocity mechanisms

The "tit-for-tat" manner of connecting to wireless CNs is quite common practice between their members. For a node to connect to a CN, there must be another node to which the connection is directed. In many cases, the reciprocal sharing obligations stemming from the participation in the CN, are described in licenses such as the Wireless Commons License (Wireless Commons Licenses (WCLs))[1]. The license dictates e.g., how traffic of other nodes should be treated and served by other nodes.

A reciprocity-based mechanism is proposed in [40]. The model considers the provision of Internet service by using Access Points (APs)s of a wireless CN. The idea is to motivate users to participate in both relaying and transferring Internet traffic. The two types of participation are balanced by a reciprocity algorithm that keeps account of the provided and consumed services of the participants. The approach is coupled with the (Peer to Peer Wireless Network Confederations (P2PWNCs)) protocol presented in [41]. The protocol divides participants into teams that manage their own APs. The reciprocity of the algorithm is implemented when team members of one AP consume/contribute traffic of/to another AP. The consumption of service is accounted based on technical receipts that are either stored in a central repository or distributed among local team APs. The privacy of users is protected as they select IDs from an available pool eliminating the need for user registration.

[1] https://en.wikipedia.org/wiki/Wireless_Commons_License

Reciprocity-based mechanisms are not only relevant to sharing network connectivity but also storage and computing resources. A Community Cloud based on sharing the computational resources of network members [42], [43], implements a reciprocity-based mechanism based on records of participants' efforts. Experimentation results indicate that the most suitable structure for community clouds should distinguish between ordinary nodes that possess cloud resources and super nodes that are responsible for the management of resource sharing. In [44] mobile devices are used for computing by borrowing Central Processing Units (CPUs) slots in a reciprocal manner. The authors conclude that the heterogeneity in the amount of available resources may not be beneficial for participants with large-scale resources.

3.1.1.2 Indirect reciprocity and reputation-based mechanisms

The concept of direct reciprocity readily expands to that of indirect reciprocity. Reputation mechanisms essentially realize indirect reciprocity.

Methodologies that can be used in developing reputation mechanisms in self-organized networks (ad-hoc, P2P, wireless mesh) and descriptions of their basic design features are presented in [45]. In order to build a reputation system, it is important to keep records of past behavior as reputation of nodes is partially build over time, to evaluate the information gathered when building node reputation, evaluate differently old vs recently gathered data and acquire immediate response to known misbehaving nodes drawing from past information records.

Among other challenges, reputation-based systems have to face the impact or liars' on peer reputation. Liars are nodes that give unreliable information about other nodes. This refers to the type of information used in order to build the reputation score of a node. The accuracy of the information received determines the credibility of the reputation metric: the goal is to remain as close to the actual node behavior as possible. Reputation mechanisms have been proposed for P2P systems and wireless ad hoc networks. In [46], such a mechanism is developed that builds a reputation score for P2P system participants. Each peer is described based on how much service (bandwidth, computation) it provides and consumes. Collaborative users are rewarded with an increase in their reputation metrics. Results show that users tend to form groups (*i.e.*, make coalitions) that eventually work to their benefit, and that reputation scores manage to enhance the cooperation of the P2P system nodes.

The CONFIDANT protocol presented in [47] for routing in mobile ad hoc networks (Mobile Ad Hoc Networks (MANETs)s) follows a similar rationale. Tamper-proof hardware is embedded in nodes and keeps account of *virtual credit* collected by nodes as they contribute in packet forwarding over the network. Whereas, the collaborative reputation mechanism in [48] keeps records of the collaboration activities of nodes in the MANET. A reputation score is kept for each node, based on monitored data and information input by other nodes.

3.1.2 Punishment of free-riders

Punishment is a quite common technique, adopted in the literature, for dealing with free riders in wireless networks. In the generic setting in [49], it is suggested that free riding should be confronted using exclusion of peers from a group as a plausible threat. Free riding is also common in multi-hop wireless networks, where nodes are expected to forward packets of other nodes. There, the consumption of bandwidth and energy serve as the main motivation for free riding behavior of nodes. These nodes enjoy packet forwarding of their own packets by other nodes but defer, either deterministically or probabilistically, from forwarding the packet of other nodes.

Reputation protocols are one way to detect misbehaving nodes.Nodes with small reputation scores are excluded from the network or community.Alternatively, selfish behaviors can be detected more directly with dedicated protocols. Detecting selfish misbehavior of mesh routing nodes in a CN is the objective of [50]. To deal with such a problem, a trust-based mechanism is developed based on the combined observations of neighbor and other nodes of the CN.

The protocol *catch* in [51], is used to preserve anonymity of users while trying to limit the free riding problem in multi-hop wireless networks. The adopted technique uses anonymous messages and statistical tests to detect the selfishly behaving nodes and isolate them. It relies on the assumption that free-riding does not appear in the initial stages of the network deployment but later, as the number of peers starts to grow. The corresponding example in CNs reflects the fact that the initial members, *i.e.*, volunteers, create the CNs based on certain principles and knowledge that are not compatible with free riding practice. Members that join the network in subsequent stages, *i.e.*, users, are often not acquainted with these principles and the importance of complying to them.

3.1.3 Community currencies

Virtual credit and reputation mechanisms serve as means to keep account of whether a node contributes or not to the network and, hence, should have the right to use it itself or not. Community currencies take these mechanisms one step further by introducing real currencies as the way to keep balance of node contributions to the network.

As long as the cost/value of nodes' contributions can be monetized, community currencies can ease the exchange of a wider set of services between members and users of a CN and reward voluntary activities. This way they can result in more healthy ecosystem, in which different actors will be able to satisfy their individual needs more easily and thus will be encouraged to participate.

At the same time, community currencies constitute themselves collaborative activities that increase the community spirit and local pride and thus can strengthen the intrinsic motivations for participating in a community network. In fact, the smooth operation of a community currency depends heavily on trust building between community members both to accept and use the corresponding currency but also to be able to provide risk-free credits that are very important for the required flow of currency. This trust is a very important asset that can play a key role in the initial birth and sustainable operation of CNs. For the same reason (existing trust and community values), the existence and operation of a CN eases the launch of a community currency.

The parallels that can be drawn between community networks and community/complementary currencies and their complex bidirectional relation are analyzed in depth in D2.4 [52].

3.1.4 Other game-theoretic mechanisms for enforcing participation

Participation in CNs can be enhanced by game-theoretic and mechanism design approaches.

The prisoner's dilemma, is the focus of [53] in P2P networks. The goal is to design incentive techniques for P2P networks while dealing with challenges related to large populations with small lifetime, asymmetry of interest in participation and multiple peer identities. In order to enhance cooperation the mechanism proposes to keep records of peer interaction and partially build reputation of peers while considering cases of false identities and hijacking.

The work in [54] uses game theory techniques to enhance cooperation in static ad-hoc networks and shows that actual incentive mechanisms have to be implemented for participation to take place. The term incentive mechanisms in this paper refers to actual credits (reputation systems or virtual

currencies). These results suggest that game-theoretic mechanisms that target to players self interest and enjoyment need to be backed up by other type of mechanisms (actual credit) to enhance the probability of user participation.

An incentive mechanism based on a Stackelberg game is provided in [55]. The authors seek to stimulate user and ISP provider participation in a scenario of a global community network. In this scenario, all the participating entities (users and ISPs) interact with the help of a third intermediate entity, *i.e.*, the community provider or mediator. The game is developed at two levels and the mediator plays the role of the leader while the users and ISPs are modeled as the followers.

A Video on Demand service on wireless ad hoc systems is the setting for the Stackelberg game presented in [56]. In order to promote cooperation among participants to upload and forward data, the content provider rewards the participants. The type of the reward varies across actual payment, virtual credit or reputation points.

In mobile ad-hoc networks one of the main concerns it to urge users to participate in the system and cooperate with other users. While some works use reputation-based mechanisms there are others that prefer credit as a plausible economic incentive to sustain participation. The work in [57] is one such case. Authors use a software protocol with a game-theoretic aspect to determine rewards and costs and use it for packet forwarding and route discovery. The design of incentive compatible routing protocol is the scope of [58].

3.1.5 Direct and indirect financial compensation

Since guifi.net involves professional entities providing commercial services, it has set forth additional mechanisms for compensating contributions of different stakeholders.

The first one is a novel compensation system that settles imbalances between network usage and network contributions. Practically, this aims at sharing network costs while acquiring resources. Professionals may assume the roles of operators that contribute to the network and consume its resources, investors that only contribute, and pure operators that only consume network resources. Operators can contribute either to the deployment of the infrastructure or to its maintenance.

The second one is the provision of donation certificates to entities that contribute to a commons infrastructure, which can lead to tax deductions. It is also possible for users who pay professionals for service provision, to have some tax deduction benefits. These exemptions are very much bound and specific to the Spanish legislation and regulation authorities.

3.2 Local data storage infrastructure

Local CN services and applications can store data locally and avoid the exposure to not well understood and often privacy-unfriendly practices of commercial data storage solutions. More often than not, such services involve the deployment of distributed cloud solutions that are deployed locally across the CN nodes and can store users' data without dependence on external cloud services.

In [35] the idea of CN resource sharing is extended beyond bandwidth resources to computing resources. Cloud computing infrastructures can be developed in various ways but face severe challenges. These challenges are due to the nature of community networks: hardware and software diversity with various options for inexpensive material, decentralized management where users contribute and manage their own resources and rapid changes in the number of contributing nodes. However, except for their challenges community clouds adopt the principles of CNs as well. In this way, CNs

have the ability to provide open and neutral cloud services where the management and the ownership of the data remain within the CNs.

In [42] an idea for developing a distributed Community Cloud that follows the topology of CNs is proposed. The goal is to regulate consumption and contribution of participant resources in the community cloud in accordance to one's level of contribution. A cloud manager is in charge of coordinating the resource sharing process and the implementation of incentive mechanisms. The incentive mechanism implements an effort-based mechanism in order to stimulate participation of nodes in resource sharing. Nodes are incentivized with rewards that depend upon their contribution, *i.e.*, effort to the local cloud system.

Developing a Community Cloud in combination with Grid Computing techniques is the objective of [59]. The aim is to develop a Community Cloud using the spare resources of network nodes while considering environmental sustainability and self-management. The community cloud replaces vendor clouds and their full access to users' resources. In a distributed Community cloud architecture, the nodes can be consumers, producers and their own coordinators of resources.

3.3 Socializing processes and tools

CNs have developed various ways in order to enhance participation and interaction among members and disseminate knowledge to them.

3.3.1 Social events and meetings

Large- and small-scale CNs organize gatherings and events to discuss not only CN organizational matters but also strengthen the bonds of community members through social activities.

- **guifi.net**, as a network of networks, is divided among smaller networks, each coming with its own local support group. Face-to-face meetings allow volunteers to discuss the issues arising from the operation of the network. These meetings take place every week or every month at the level of the local guifi.net communities and once a year at the level of the whole guifi.net.
- **Ninux** Similar practices are followed in Ninux and its own CN islands, with meetings organized periodically at local level. Global meetings and events take place every few years.
- **AWMN** Face-to-face meetings are also organized in AWMN by its Association to discuss important organizational matters. They use in particular the General Assembly to regulate and decide about the governance of the network and the election of boards. In most cases, groups of users take advantage of these events and go out together for coffee or drinks when they are over.
- **Freifunk** c-base gatherings and the annual "Wireless Community Weekend" event is the way that Freifunk members and organizations get in touch with each other.

3.3.2 New member induction processes

Depending on the mentality and philosophy of the particular CN, interaction among network members is a natural prerequisite for one's access to the network. The way that this interaction is later on retained, determines to a large extent the individual user participation level.

In **AWMN**, for example, newcomers are urged to register and communicate with nodes of physical proximity to them. After communicating with the node owners, they are able to receive advice about

the equipment they need and acquire assistance from existing members in setting up their own nodes and joining the network. Many node owners provide public contact information for others to contact them. In cases that actual interaction with node owners is not possible or for complementary assistance, users can register to the website and post their questions in the CN's forum.

3.4 Education and training

Education and training of CN members is often an important aspect of CNs, addressing their members desire for acquiring new skills and learn more about networking and radio technologies. Seminars, workshops and online manuals are the main deliverables of this line of effort, invested typically by members of the volunteers' group but also by other CN members.

3.4.1 Workshops and seminars

Several workshop and seminar events are organized by existing CNs. Experienced members share their knowledge with new members, exchange ideas and present available technical solutions. Examples follow below.

- **AWMN** Face to face meetings and workshops have been taking place in AWMN not only for the proper organization of the network but also for knowing new members, disseminating knowledge and technical expertise, interacting with people that have the same interests and strengthening the bonds within the community.
- **Sarantaporo.gr** organizes seminars and workshops to inform people about the operation of the network and share knowledge over the wireless networking principles and the development of community networks. The latest workshop was organized in conjunction with netCommons in November 2016.
- **guifi.net** is quite active in organizing events. It hosts workshops and learning seminars for end users or professionals known as guifi labs[2] [3], the Salut, Amor i Xarxas (SAXs)[4], or supports related events GNOME Users And Developers European Conferences (GUADECs)[5], the e-week in Vic[6]. It also provides support for the World Summit for Free Information Infrastructures.

3.4.2 Online material for DIY fans

CNs invest effort to derive manuals and how-to documents so that users can learn more about technical matters and be able to set up their own nodes. Freifunk, Ninux, AWMN, guifi.net follow this practice.

- **Ninux** contains detailed technical instructions on how to set up a network node, the hardware needed, Frequently Asked Questionss (FAQs)s, guides, etc. that aim at providing all the useful information needed for an individual to participate in the network on his/her own.
- **guifi.net** instructions to setting up a node, guide newcomers through a three-step process[7]. In the case that users do not have knowledge of an access point they can connect to, they are

[2] http://www.guifiraval.net/
[3] https://guifi.net/en/event
[4] https://sax2016.guifi.net
[5] https://en.wikipedia.org/wiki/GNOME_Users_And_Developers_European_Conference
[6] https://twitter.com/eweekvic
[7] https://guifi.net/en/threesteps

advised to use the forum, or actual contact info of node owners, or even urge their friends and family to take part in the network and set up a node.

- **Freifunk** in the memorandum of understanding[8] state that they acknowledge the fact that participation in the network can be a challenging process. However, they encourage users to ”take matters into their own hands” instead of relying to ”experts” and behaving as consumers of service rather than participants.

3.5 Local applications and services as incentives

The services and applications running over the network could themselves be considered as mechanisms motivating persons to join the network[9]. Such services may range from network connectivity to communication and entertainment. The applications that have attracted the main interest in the CN literature are:

- **VOIP services** A VOIP scheme was presented in [60] building upon an existing scheme, the Peer-to-peer Wireless Network Confederation (P2PWNC) that considers nomadic users as consumers of bandwidth and residential WLAN owners as providers of bandwidth. This scheme is applicable to CNs with appropriate coverage capabilities. The VoIP application is analyzed based on the P2PWNC architecture.

  Another approach of a VOIP service for wireless environments is the focus of [61] and [62] in a setting where nomadic users have community-based Internet access but is generic enough to be implemented in other cases as well. The implementation of wireless communication services faces challenges such as trust on nodes, data privacy and unspecified conditions of the wireless environment (i.e., poor signal, transmission delay etc.). A secure VOIP scheme is developed in a residential Wireless Local Area Networks (WLANs) and is performance limits (i.e., capacity, service quality, security) are investigated. The results acknowledge the potentials of the scheme in a wider scale implementation.
- **Community clouds** Clouds have attracted a lot of attention since they are seen as fundamental privacy enablers, i.e., store the data of the CN locally, without needing to interact with the public Internet 3.2.
- **Crowdsourcing applications** match very well the participatory nature of wireless community networks, i.e., participatory networking [26] and the strong community-oriented social structure met in most developing regions. In the crowdsourcing paradigm, individual users solicit information, content or service from groups of people. The community dimension only strengthens the case for such applications since the community bonds serve as additional socio-psychological incentives for the active participation and contributions of end users. The common resources shared by the members can serve as the media where users (mobile or not) connect to post tasks or get informed about available task announcements. Users receive explicit reward such as monetary payment, virtual credits of services that match the services they offer [63].

Some CNs exhibit a wide variety in applications such as guifi.net, AWMN, Ninux, Freifunk, while others are at a more initial stage of service and app provision. In CNs like Sarantaporo.gr and i4Free,

[8] https://github.com/freifunk/MoU/blob/master/FreifunkMemorandumofUnderstanding_en.md

[9] There also those doubting that local services can make an impact on CNs considering that public Internet covers any application needs on the side of the user i4free [7].

the main service of interest is internet service. Networks built by people with technological background tend to elaborate more on the provision of non professional services. Also, the size of the network and the years of its existence play an important role in their implementation. The core of these networks contain at least a main blog and website for the network information, forums where members can communicate with each other and other distributed services such as chat, VOIP communication, mailing lists etc.

- **AWMN** services are of great variety. Users are able to communicate over VOIP, forums, mailing service and instant messaging and exchange data with P2P file sharing, File Transfer Protocols (FTPs) servers, access video, audio, and local cloud services. They are also able to have access to a number of entertainment activities such as multi-player gaming, broadcasting, live streaming and radio stations. For the information of users within the network and their education to technological matters it is possible to follow online seminars via e-learning, get informed in community wikis, follow the weather, find the information using local search engines (i.e., Quicksearch, Wahoo, Woogle) or even develop texts using collaborative writing services. Internet service is not of the network's main provision and it depends on the node owners' whether they would like to share their internet connection or not.
- **Freifunk** provides services like chat, email servers, mailing lists, wikis, radio and podcast services, blogging, collaborative editing, community calendar and other.
- **Ninux** basic services include mailing lists, VOIP server and other servers or service lists mostly known within the network users.
- **guifi.net** The announced services of guifi.net relate to Internet gateways, Web proxies, VOIP servers, FTP or shared disk servers, XMPP instant messaging servers, IRC servers, videoconferencing servers, web servers, broadcast radios and mail servers.

  The real deployment of cloud services in the *Cloudy* distribution in guifi.net aim to stimulate CN member participation. The presentation of a community cloud network is backed up by the implementation of *Cloudy* [64]. The community cloud *Cloudy* uses open source software and each CN members can install cloudy and add their own resources to the community cloud [65].
- **FFDN** CNs provide services such as Virtual Private Networks (VPNs), self hosting, internet cube, BitTorrent tracker, IndeCP or internet service. These services are provided non-profitably (covering costs) or with small profits.
- **Sarantaporo.gr** services offer Private VoIP service, video streaming, weather monitoring but the basic service of all is internet service.

3.6 Lawful framework of operation

When the operational framework of CNs (legal status, rights, obligations) is not well defined, attracting new participants becomes harder. The existence or lack of visible support of CN initiatives by the state or local administration also has an impact on users' decisions to join or not the network [66]. For example, When local authorities or another third-party organization with clear legal status are involved, e.g., by signing licenses, the user concerns are easier overcome and the decision to participate appears as far less risky.

The response of most CN initiatives to these reservations is to develop legal entities, and set forth licences and agreements as legal documents specifying the terms and conditions of participation in the network.

3.6.1 Operation as legal entities

Indicatively rather than exhaustively:

- **guifi.net** In guifi.net [2], four year after its inception, a group of network users created the guifi.net foundation. The foundation was created with as a nonprofit legal entity for managing operational and funding issues regarding the guifi CN. To this end, it has developed several other legal mechanisms and tools (ref. 3.6.2). The legal entity of guifi.net is recognized both at local and national level.
- **AWMN** has founded the "Association of AWMN", a legal entity with a non-profit character representing the network to third parties. The Association has certain rules reflecting its main purpose of supporting and promoting ICT services.
- **FFDN** is a federation of CNs, each of which has been declared as a non-profit member organization and they are registered as telecom operators according to the French legislation.
- **Sarantaporo.gr** has developed a non-profit civil partnership that follows a set of articles and is subject to the Greek legal framework about NPOs.
- **Freifunk** association called Forderverein freie Netzwerke e.V., is the reference authority (NPO) that gathers the responsibilities of funding and operation of the website and other media platforms. It is composed by a variety of networks that expand from Germany to Switzerland and Austria and is governed in a decentralized manner.To this purpose, for each of these network a local group is formed as a non-profit organization and undertakes responsibility for their local CN. They deliberately avoid hierarchies (of knowledge) that would give the participants the feeling that they are consumers of service (passive users).

3.6.2 Licenses and Agreements

Besides the legal status, CNs normally make use of legal documents, such as Licenses and Agreements, to specify the frame of their members' participation and their own interaction with third-party entities.

- **guifi.net** has devised certain legal documents determining participation rules: a Network Commons License (NCL) for establishing the rights and duties of subscribed participants and collaboration agreements that define the terms of condition of third party collaboration within the network. The Foundation of guifi.net is always present in these agreements as a central hub.

  Any professional that wants to perform economic activities and use a significant amount of resources of the network has to sign an Agreement with the Foundation and participate in the compensation system (ref. section Section 3.1.5). There are three types of Agreements, depending on the type of contribution professionals make to the common infrastructure. The first one, *Type A*, assumes that all of the infrastructure contributed by a professional will be incorporated in the commons; the second type, *Type B* applies when parts of the contributed infrastructure is attributed to the common infrastructure; and the last type, *Type C* refers to professionals that don't contribute infrastructure but use the one already deployed in the network.
- **FFDN** The NCL is adopted by FFDN as well. The issue of net neutrality is specified within the NCL. ISPs of FFDN are bound to use public router IP addresses for each of their subscribers. Collaboration agreements are also present in guifi.net and FFDN. A Reference Authority is present in FFDN for legal representation of the local CNs and their members.

- **Freifunk** The PicoPeering Agreement initiated by Freifunk promotes the free exchange of data within the network. The Memorandum of Understanding (MOU) is also used in Freifunk to declare the basic principles of network operation.

3.7 Discussion

Several of the incentive mechanisms that are described in Sections from 3.1 to 3.6 have never gone beyond the paper analysis stage. On the other hand, several others are indeed applied in existing CNs. The financial compensation system of guifi.net, the social events, meetings and workshops organized by many CNs, the adoption of licences in Freifunk and guifi.net, as well as the introduction of a lawful operational framework serve, one way or another, as incentive mechanisms that motivate the participation of different types of stakeholders in CN initiatives, as shown in Table 3.1.

Some of these incentive mechanisms apply almost invariably to all CNs. The lawful operational status, for example, is mandatory if the CN wants to attract critical masses of users, but also professionals and the support from public administration. Equally common among CNs is the care for social events and meetings that can strengthen the links between their members and satisfy socio-cultural motives of users. On the contrary, incentive mechanisms of economical nature, such as the financial compensation scheme and the donation certificates issued bu guifi.net for tax deduction purposes are more relevant in CNs that support commercial operations over them.

For sure, it would be rather wise to match the incentive mechanisms with the different stakeholder types. Hence, volunteers would be more responsive to incentive mechanisms that underline political and cultural causes; professionals would respond, maybe exclusively, to incentive mechanisms with economic implications; and local authorities will be much more prone to get involved when they realize that public expenses can be saved or some political strategic objective be served through this involvement.

Mechanisms	Volunteers	Users	Professionals	Public administrations
Direct reciprocity		x		
Indirect reciprocity		x		
Punishment of free-riders	x			
Community currencies		x	x	
Donation certificates			x	x
Financial compensation			x	
Local data storage infrastructure		x		
Social events and meetings	x	x		
New member induction processes		x		
Workshops and seminars		x		
Online material for DIY fans		x		
Local applications and services		x		
Operation as legal entities		x	x	x
Licenses and Agreements		x	x	

Table 3.1: Incentives mechanisms and relevance to stakeholders.

By far, the majority of incentive mechanisms target the users of the CN. One aspect that is not well understood is how the effectiveness of a mechanism varies with different features of the community;

namely, if we could have a characterization of a community according to a fixed set of attributes (urban vs. rural, educational level, professional background, dominant political preferences) that could predict which incentive mechanism would best mobilize its members. An important parameter in this context is the size of the community. Characterizations along attributes is easier if the community is small and with roughly uniform interests and professional background. As their size grows, such characterizations become harder and so does any attempt to predict the suitability of incentive mechanisms.

4 guifi.net and Sarantaporo.gr: two case studies

In this chapter, we look into more detail into two CN instances, guifi.net and Sarantaporo.gr that will serve as case studies in netCommons Task 2.2. The specific instances were chosen for a number of reasons.

Guifi.net instantiates the richest ecosystem of stakeholders, explicitly distinguishing between network infrastructure and services and catering for commercial services over the CN by the so-called professionals. It is broadly recognized as a success story and has attracted a lot of publicity both within Europe and worldwide. It definitely sets a distinct model of CN sustainability that could be replicated by other CNs. Finally, there are several publications revolving about the CN initiative and members of the guifi.net foundation are involved in the netCommons project. Both these facts ensure access to details about the network operation and business model that are required for our analysis of incentive mechanisms.

Sarantaporo.gr presents a different paradigm. The network is younger and the community is smaller and more homogeneous regarding its economic activities (almost exclusively of the primary sector such as farming and stock farming). Much of the network evolution so far has relied on equipment donations by the Greek Foundation for Open-Source Software and funds from an EU R&D project budget. An economically sustainable model for its operation is very much an open question and, for sure, it needs to engage more actively the local population. The tight links with the Sarantaporo.gr and the involvement of their most active members in the netCommons project has eased the availability of required information and the work with them. Two of their most active members, George Klissiaris and Vassilis Chryssos, are now part of the netCommons project, contracted by AUEB. The interaction with them has resulted in several face-to-face meetings and the organization of a workshop (ref. netCommons deliverable D3.1) to exchange ideas and receive suggestions about the future of the network. Developing an economic model that will fit Sarantaporo.gr and ensure its sustainability has been one of the main topic of these meetings.

With these two CN instances at our focus, two main study items plausibly emerge as key themes of the Task 2.2 activities in Y2:

- How well tuned are the incentive mechanisms in the guifi.net for the different types of stakeholders and to what extent could they be further improved and optimized?
- Which elements of the guifi.net model could be exported to the Sarantaporo.gr CN and how could this be done?

For the time being, we summarize below all important information about the stakeholders' incentives and incentive mechanisms in place in these two CNs. In the case of guifi.net, these have emerged from prior work and publications and the work in Task 1.1 of netCommons as reported in Deliverable D1.2 [1]. In the case of Sarantaporo.gr, the main information comes from questionnaires and studies conducted by netCommons in Task 2.1 and reported in Deliverable D2.2 [7].

4.1 Guifi.net stakeholder incentives

Guifi.net is one of the leading CN instances, not only in terms of size, but also regarding its sustainability model and the way different types of stakeholders are motivated to engage in the network.

4.1.1 Volunteers

They have built and currently manage a CN with considerable impact [2]. Their incentives are mainly political and socio-cultural: they aim at an alternative and more socially sustainable model of network infrastructure management drawing on the commons' economic theory. The network now counts almost fifteen years of life and has evolved to an alternative telecommunications network, with governance and service provision models that depart radically from traditional telecommunications models. Ideals and aims such as net neutrality, bridging the digital divide, openness, privacy, autonomy and self-organization rank top in the network's charter and operational principles. The group of volunteers are highly motivated by their aspirations to serve and share the aforementioned concepts and protect the rights of different stakeholders in accessing the network. To this end, commercial and non-commercial activities are supported in the network as long as they comply with the rules of the network. They are interested in promoting creativity and innovation, economic activities and protecting consumer rights.

Their goals have been quite clear from the start and continue to maintain their cohesion while evolving into different directions, *i.e.*, cooperating with professionals, ISPs and telecom companies to extend the technology and the services that can be provided by or within the network. Academia has been involved greatly in the creation of guifi.net and some of the members of the Foundation are academics and researchers.

4.1.2 Users

Users in guifi.net are mainly described by socio-cultural motives such as accessing and experimenting with ICT technologies, applications and services, social interaction and communication with other people. The economic dimension is also important in that they get broadband access at better prices than commercial ISPs make available. This becomes possible by subscribing to one or more of the professionals that offer services (including Internet connectivity ones) over the guifi.net CN. The network has started and expanded mainly in the rural areas of Catalonia that lacked access to ICT services and their users are mainly the residents of those areas. Its nodes have expanded though apart from small villages outside Catalonia to provinces of Valencia and Castellon.

4.1.3 Professionals

Professionals have economic motives to participate in guifi.net. By using the infrastructure of the network they are able to offer services to the customers in exchange for economic compensation. They are either individuals or enterprises able to compete for providing services to their customers but without any speculation on the network infrastructure. Professionals have to cooperate in the network deployment and operation independently of their competition for customers. The economic sustainability of the network depends greatly on the integration of professionals in the guifi.net ecosystem. The most characteristic example of professionals that participate in the network are small ISPs that have seized the chance to provide internet connectivity to guifi.net users.

4.1.4 Public administrations

Public administrations may participate in the network by offering public resources (roads, ducts, storage rooms, etc) for laying out the network, by donating/purchasing equipment for deploying network infrastructure, or connecting to it as customers to satisfy their own connectivity needs. In first two cases, the main motivation is their direct interest in matters such as bridging the digital divide and ensuring access for the residents of the local area to ICT services. Each municipality can choose the way it can participate in guifi.net and the services it can promote to the citizens. As an example, more than 50 villages in the province of Castellon offer, through guifi.net, free web browsing in the Internet to their citizens.

4.2 guifi.net incentive mechanisms

Guifi.net has been trying to make use of very different mechanisms to incentivize participation in the CN and cooperation among its participants. These mechanisms address all types of stakeholders and respond to all the different dimensions of intrinsic incentives described in section 2.

First of all, the volunteers' group that runs the network has devoted significant effort to put in place all those legal tools and transparent processes that ensure its lawful operational framework and help establish trust in the network purposes among its participants. These include the:

- **Wireless Common License (WCL)**: In order to establish terms and conditions for network use, expansion and participation, the g guifi.net has established the Wireless Common License (WCL). This is inspired by the Creative Commons License and serves as a reciprocity mechanism. Results have shown that the establishment of this license was crucial for the development of guifi.net as an open and transparent network. It explicitly states the reciprocal terms for participating in the network, *i.e.*, receiving and provide connectivity and incorporates transparency in applying priorities of traffic within the network. Matters of content and services, liability of the network, use of the spectrum, network management, QoS and the network's free and open character are explicitly stated within the license. All possible entities involved with the network, individuals, communities, organizations, companies, governments or any type of organization, have to comply with the WCL[1][2].
- **guifi.net foundation**: guifi.net includes the creation of the guifi.net foundation. It is the legal entity of guifi.net and its foundation goals serve the protection and promotion of the whole network. It is run by volunteers and it takes on organizational roles such as maintaining and enforcing the compliance with the WCL, developing and promoting innovating activities and new projects, expanding and operating the network, disseminating tasks and activities, coordinating and managing. It has implemented a set of tools such as the Collaboration Agreements, the Conflict Resolution system and the Economic compensation system to enhance the participation of different stakeholders. It consists of a board of unpaid directors and workers. The economic contributions to the Foundation come mainly from the services it offers to professionals.
- **Conflicts' resolution system**: This system has been developed with regards to addressing conflicts of interest among network participants in a discrete and explicit way. The necessity of such a system became even greater as the guifi.net network started to scale and its creation was empirical based on the learning experience gained from past situations. The Foundation

[1] https://guifi.net/en/WCL_EN
[2] http://wiki.commonstransition.org/wiki/FLOK:_Open_Technical_Infrastructures

took the initiative to develop and implement the conflicts resolution system when some of the conflicts between participants started to jeopardize the future of the whole guifi.net project.

- **Collaboration Agreement**: Collaboration agreements follow a set of templates that have been established to regulate interactions of professionals with the network. They come into three different types (Type A-full commitment, Type B partial commitment, Type C opportunistic) depending on the level of contribution of professionals to the infrastructure. The Collaboration agreements consider the Foundation as a hub, as it is always the entity present for enhancing the level of trust. Public administration use the collaboration agreements for participating in the network infrastructure and ease their legal limitations.

Likewise, it has set forth processes and tools that aim at further cultivating the social dimension of the network and the associated community purposes. These involve:

- **Face to face meetings**: Face to face meetings are employed in guifi.net for coordination of the volunteer team in organizational matter along with social events for knowledge dissemination and sharing, strengthening bonds among community members etc. A global guifi.net meeting happens once a year to gather all the community participants, discuss about the project in technical, organizational and social aspects. The meeting i.e. SAX is open not only to guifi.net members but to anyone interested in technology, networks and the commons. Local meetings of local guifi.net networks are performed in a weekly or monthly base. Their goal resides in working on network projects and assisting new comers to participate in the network.
- **Events**: Events are often organized by guifi.net. The goal of events (workshops and seminars) are to incentivize network members in participating and cooperating, enhancing their knowledge, cultivating the community spirit and strengthening guifi.net community bonds, etc
- **Communication mechanisms**: Mailing lists, the website and social media platforms are some tools that have been employed in guifi.net for enhancing and regulating member participation. The website [3] is the central coordination and participation tool as it incorporates, information regarding the network, its basic access tools, support systems such as the social network of guifi.net, the mailing lists, the forum as well as chat services. The mailing lists, the forum and the social platform are one of the most popular discussion tools.

Equally, if not more, important are mechanisms that provide incentives of economic nature to its professionals and other participants.

- **Economic compensation system**: guifi.net employs a compensation system to regulate economic interactions within the network and share network costs. The compensation system aims at keeping track and regulating the consumptions and contributions of participants. It is composed of three basic components: a) the compensation agreements, b) the compensation tables and c) the compensation settlements [36]. The compensation agreement is applied to various types of stakeholders. For volunteers that deliver services in a best effort way, non-profit organizations or collectives that offer services for economic compensation, professionals or enterprises that are legally qualified to offer services in return for economic compensation, investors, contributors or public organizations that are contributors in the common infrastructure of the network. The agreement defines the motivations and scopes as well as the participation guidelines of all the above stakeholders that use a certain amount of network resources.

  The compensation tables aim to establish the compensation criteria for promoting investments, maintenance and coordination among participants and support economic sustainability of the network. They are defined in monthly-based open meetings restricted to those that have signed

[3] https://guifi.net/

specific agreements. Practically, participants are operators and service providers, public administrations or investors and the guifi.net Foundation. All the participants are able to make proposals that should be approved either by consensus or by vote. In particular the guifi.net Foundation has the ability to submit compensation proposals for the next compensation cycle and exercise its veto on the proposals presented whenever necessary. The rest of the participants are able to vote and suggest improvements over the proposals if necessary. Investors are also able to keep track of their contributions and veto any decision related to them that does not express their will.

The compensation settlements are responsible for balancing the contributions and expenses of each participant with regard to the common network resources. Each participant reports their expenses through an expenditure declaration. The contributions are issued in bills that declare whether the contribution was in terms of infrastructure deployment or maintenance. Participant balances are computed using a spreadsheet applying the criteria and rules of the agreement and compensation tables and they are ultimately settled among the Foundation and the participants in terms of payment. Stakeholders can either contribute (to) or consume network resources or both. Those that contribute and consume, use the network for providing their services in return for economic compensationThe participants whose primary role is to contribute are considered investors and those that only consume network resources utilize it purely for the transport of their services. The contribution is reported in terms of monetary contributions i.e. euros and the consumption is measured in Terabytes.

- **Donation certificates** Donation certificates are issued by the guifi.net Foundation to the end users. End users are basically customers of professionals that can be considered as donors. Their donations are the indirect economic contributions to the infrastructure. According to the rules of the Spanish regulation donations can be subject to tax deductions.

Last, but not least, the guifi.net devotes effort to developing:

- **Services**: guifi.net contains various services with either public or private access. Public services can be distinguished to network services and user services contributed to the CN members by network participants. Network services contain servers such as network graph, DNS, Network Time Protocols (NTPs), Logs, Lightweight Directory Access Protocols (LDAPs) as well as bandwidth measurements and wake on LAN [64]. User services include proxy-based and tunnel-based Internet access, web pages, VOIP, data storage, mail, games and P2P servers, TV and audio stations, weather stations, linux mirrors, webcams, CVS repositories and server virtualization. Although there are a number of services deployed, Internet service obtains almost 55% of the total use of services.

  A release of a GNU/Linux distribution named Guinux offered to users services such as HTTP proxy, DNS systems and MRTG graphic interfaces. End users could participate in Guinux in an easy without having to learn or deploy technological services themselves. Cloudy distribution came as an effort to provide Community Cloud services. Cloudy incorporates open source software and has been implemented in guifi.net. It has been designed as a platform created by employing resource sharing among users and collaborative access of resources and built-in services.

- **Education and training material**: Free guides and online material are developed within guifi.net in order to assist newcomers and members of the network in educating themselves and learn ways to join, use, expand and face troubleshooting problem of the network.

4.3 Sarantaporo.gr stakeholder incentives

The CN in the Sarantaporo area is both younger and significantly smaller than guifi. There is practically no involvement of professionals in the network, and so is the case with public administration bodies, such as the local Municipality, even if they acknowledge its potential to serve the local population needs.

4.3.1 Volunteers

They are the initiators of the endeavor, who ran the whole set up of the network: from the network design to the deployment of the nodes and the final fine tuning of antennas. From the beginning till now, this group of volunteers remains small and tight. Few of them are very active and members of the core team of Sarantaporo.gr Non-Profit Organization (NPO). The remaining ones are locals, who mostly lack any advanced technical expertise, but share the belief in local socio-economic development through exploitation of modern technologies.

The core team of volunteers, the members of the legal entity, are those responsible for the management and operation of the CN. They are extremely motivated by political and socio-cultural incentives. The political dimension focus on bridging the digital divide and ensuring equal participation in the digital society, as well as supporting the commons ideas. Socio-cultural motives mainly consist in the idea that digital technologies can become the basis for the socio-economic boom in the remote underserved area of the Sarantaporo village.

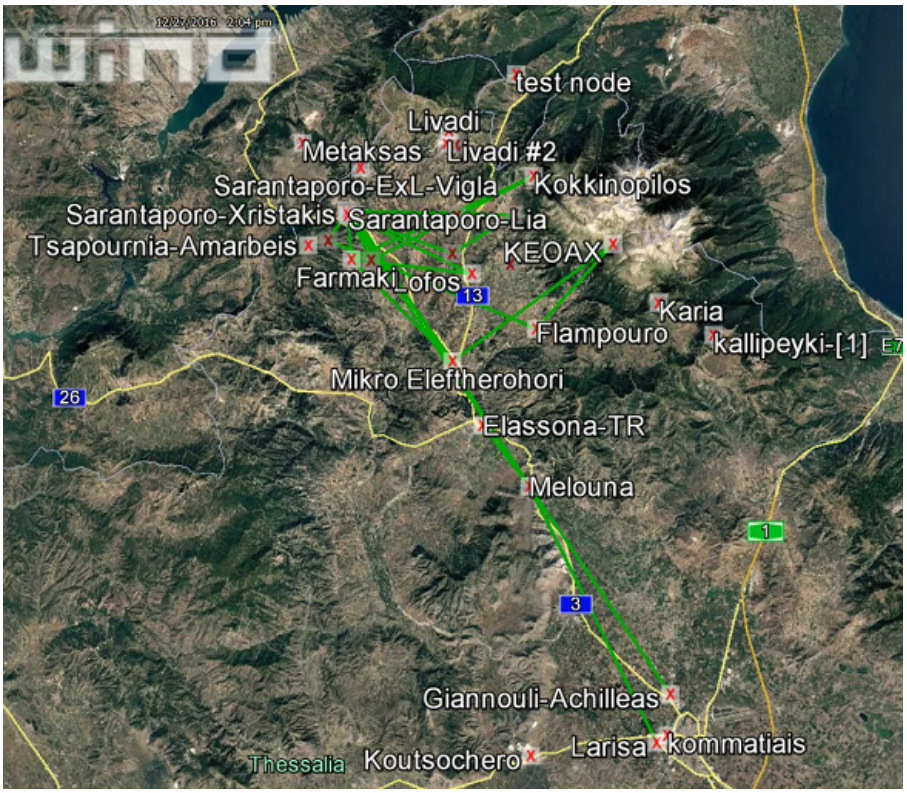

Figure 4.1: Overview of Sarantaporo.gr network.

4.3.2 Users

The Sarantaporo.gr team strives to create a modern telecommunications infrastructure in the hands of local communities, which will be managed, maintained and further expanded by the users themselves. Besides the possibility of broadband Internet, the infrastructure is and can be used in parallel for the development of digital services with local interest. The access to the internet is the condition that allows to combat the digital illiteracy and the digital divide. The infrastructure management by the community itself is a key feature that allows the participation of citizens in decision-making, organic network expansion and its integration into everyday life.

The majority of users, in general, have a passive role in the CN. The Sarantaporo.gr team makes persistent efforts by organizing info-points, multiple discussion sessions at various places in the area to involve them more actively in the endeavor. However, they seem to be indifferent to participating in any way other than consuming. Except for some few cases, mostly represented by middle age and elderly, who seem to appreciate the commons idea, the rest do not seem to be willing to engage more in the CN.

The greatest incentive to utilize the CN for all users is its openness and the mobility it offers. The CN has almost full coverage of the villages it is installed in. This means that it provides continuous connectivity no matter where in the villages the users are, either at home, at the local cafes, at the church or at the square. This is reported to be one of the most important values the CN brings and serves as an incentive to use it due to the offered reliable continuous connection. The villages are small and their population does not exceed 5000 permanent residents; Fig. 4.1 reports the Santaporo area with the long distance links that interconnect the villages as well as isolated hamlets.

At the same time, the simplicity of the network joining procedure is highly appreciated: it suffices to just click on a single introductory page, without any registration or any other additional steps.

The users' category can be further subdivided into:

- permanent local inhabitants (children, young people, middle age users, professionals and elderly),
- visitors (relatives of locals, who come periodically, and occasional visitors),
- local organizations and academia.

Each of these groups has different motives and it find rewards and incentives in different goals. The following list attempts the description of the incentives that are most effective for each group, stressing in particular what are the intrinsic incentives, *i.e.*, those that are embedded in the system and just need to be highlighted, that lead to the success of the initiative.

Children: The youngest users, intended here to include also teenagers of the network use the network for reasons such as:

a) Communication with their friends, relatives, classmates and teachers. The majority of villages do not possess schools and most pupils need to travel in a daily basis to nearby villages. Having access to e-tools eases their communication significantly.

b) Search of information related to educational activities and school projects, online libraries and encyclopedias, online lessons / e-classes. There is a recent story about a girl living in one of the villages integrated to the Sarantaporo.gr CN, who managed to excel in this year's national university entry exams without any other assistance than online support and e-classes from her teachers. In her interview[4], she states clearly that the easy and

[4] http://www.sarantaporo.gr/node/395

quick access to the Internet through the CN served as a catalytic factor to her success.

c) Entertainment reasons. Children have access to social networks, games, videos music and movies for spending their leisure and entertain themselves.

Young people: Young people refers to an age group of 18 to 35 years old, thus partially overlapping with the Children group. As residents of the remote agricultural areas young people use the network because they need to contact and communicate with their friends, find ways to spend their spare time and entertain themselves, seek information about job opportunities, seek further education opportunities, access e-government and e-banking services and perform online shopping.

Elderly: Elderly refers to people that are above 65 years old. For this age group of residents, there need for communication is very important because they find themselves feel lonely, missing their children and grandchildren that do not live with them anymore, they feel insecure because of the isolation and their difficulty in moving and they usually have low income. These types of needs can function as incentives for them to use the network and communicate with their relatives, having their medicine prescribed remotely without the need to move and spend money on traveling to medicine centers for their frequent medicine prescriptions.

The CN affects and is being used indirectly (in economic and/or social terms) by the following groups:

Relatives of permanent local residents: The relatives (children, grandchildren etc) of the permanent local citizens that reside away from the villages worry and seek ways to communicate with their own people that reside in the villages. As it is not easy for them to visit the area frequently due to their work and family obligations, Sarantaporo.gr can bridge the distance with the use of ICT services.

Visitors: Visitors of the area can either be people with origins from the local area or tourists that have never been there before. Visitors that come to visit their families require internet connection and select the destination and the length of stay with this criterion. Tourists could use the internet connect to get information over local shops, monuments and transportation.

Both relatives of locals, living elsewhere and occasional visitors and tourists report that the CN existence is a reason and incentive for them to prolong their stay in the area. It gives them the opportunity to either work distantly, to stay up to date with their obligations at home, to keep good communication with their everyday lives. This is beneficial to the locals as well, since they are satisfied with the longer visits, the sense of loneliness is quite diminished.

Local organizations and associations: During the last decade, local organizations and associations are continuously facing various problems, either due to the economic crisis in Greece or due to lack of interest of locals to actively participate. They face continuous fragmenting and experience difficulties in finding financial resources to carry out their activities. Apart from their decline in number of people and resources they observe that there is no influx of new members. Sarantaporo.gr provides them with an easy way to access their current and potential members.It also assists them indirectly, while trying to rebuild the common spirit, which in the past used to be natural in the area.

Local professionals: The professionals in the area covered from Sarantaporo.gr are mostly farmers, breeders and local shop owners. Currently, they compose one more group of users for the network. The term professionals here does not refer to those that use the network infrastructure to provide their services as it was introduced in Section 1.1. Integrating the group of professionals to the network remains a principal challenge for Sarantaporo.gr.

Farmers and breeders face problems as their income steadily decreases during the last years

due to the shrinking market and huge competition. They seek better markets for their products and better and cheaper suppliers for raw materials and information for the market price of their production. However, they are usually not very comfortable with technology.

Local shop owners and merchants are confronted with similar problems. They do not have easy access to the potential buyers in the area due to distance and communication issues. They are interested in new and economical ways of communication and promotion or advertising of products or services to their customers in the local market.

The professionals, both locals and from other areas, seem to appreciate most the CN. The impact on their everyday activities is monetary measurable, as various costs related to their economic activities are provably reduced. Local professionals are mostly those, who are willing to pay and contribute to the financial sustainability of the CN. Some of them belong to the category of local volunteers, being node owners or providing labor and financial contribution, when needed. As a simple demonstration of the current use of the CN and benefits from it, suppliers in the area report that they use mobile terminal devices connected to their central Enterprise Resource Plannings (ERPs) - Customer Relationship Managements (CRMs) systems. The continuous availability of internet connection in all those villages has contributed to optimization of all work procedures, making them easier and faster and at the same time their customers - local professionals are better served and are definitely more satisfied than before.

4.3.3 Professionals

The group of professionals as it was described in Section 1.1 remains at very early stages in the Sarantaporo.gr network. Professionals can potentially find customers for their services through the network infrastructure in return for some economic benefit. There is an example of a company name modulus that provides VOIP services via the network in exchange for economic compensation[5]. Other companies appear to get interested in this as well. The conception and development of a Sarantaporo.gr suited business model could ease the participation of interested professionals.

4.3.4 Public institutions and administration authorities

Local authorities: Local municipalities and regional administrations possess online services that not accessible to all citizens of the region. They do not have any way for direct and mass communication with citizens. Also, there is a continuous complaining of locals about the lack of telecommunications infrastructure and internet access.

Local authorities, in particular the Municipality of Elassona and Thessaly Region have great interest in the CN existence. It gives a way to include local citizens in the local government affairs, use e-government services as the e-tax platform, or an online version of various state documents; without the Sarantaporo.gr network these would be deemed impossible for many locals. Despite the benefits the CN provides and value it would have to local authorities, they do not take any active part in it. No will for any kind of contribution to the CN development and extension has been shown on their part till present. The probable reasons for this indifferent attitude is the incapability to understand the CN model of operation and management on one hand and the resistance to innovation and innovative ways of problem solving from a conservative point of view, on the other.

[5] https://www.modulus.gr/

Academia: Universities, institutes and research centers seek ways to apply in practice their theoretical achievements and provide contributions to the benefit of the local communities.

The University of Applied Sciences of Thessaly, which is the CN's pro bono provider of broadband access has both political and socio-cultural incentives to be a part of the Sarantaporo.gr case. They can easily disseminate the knowledge produced and at the same time the CN is open to being their testbed for research activities. Furthermore, they have the opportunity to socially contribute, covering the great need of a remote area to having Internet access and being equal participants in the digital society.

4.4 Sarantaporo.gr incentive mechanisms

Little exists to report on this front for this CN:

- The Sarantaporo.gr has been established as a NPO entity. This increases trust in them and enables them to carry out financial transactions.
- Educational material and instructions for setting up a network node can be found at the webpages of the CN for those who are DIY funs.
- There have been some efforts to provide local services over the CN but have not really realized so far. Part of the work in netCommons WP3 addresses this gap.

4.5 Comparing the two CNs and possibilities for transfer of know-how

Summarizing, and trying to draw parallels between the two CNs, we could note the following:

- they have both been initiated by a small number of volunteers who had the ambition and the knowledge to set up a network
- the motivation in both cases was to fill in the Internet connectivity gap in rural areas

On the other hand, the two CNs exhibit a lot of differences, which can, at least partly, be justified by the age of the two CNs. The primary ones are:

- the guifi.net is a much (two to three orders of size) larger CN than the Sarantaporo.gr
- the community in Sarantaporo.gr, also as a consequence of its much smallest size, is much more uniform in terms of economy activities (primary sector)
- guifi.net has engaged the full set of possible stakeholder in its network, including professionals and public administrations
- guifi.net has a far richer set of mechanisms in place that aim to encourage the participation in the CN, or overcome reservations against doing so.

Overall, guifi.net has gone a long way to distill, after experimentation and testing, incentive mechanisms aiming at its long-term sustainability. This task is by no way complete or optimized; it has been rather a dynamic heuristic process that has evolved over time in accordance with the community response and the overall telecommunications landscape.

On the other hand, Sarantaporo.gr is a young network in search for a business model that can ensure its sustainability, in the multi-dimensional sense of the term that is analyzed in netCommons deliverable D2.2 [7]. If guifi.net is a success case, it is plausible to ask whether this success is exportable to Sarantaporo.gr. This will be the main theme of work in Y2 of T2.2, as prologued in the beginning of this section.

5 Conclusions and next steps

Community networks represent a strongly distinct as well as adequately versatile networking paradigm that departs radically from conventional commercial networks. This departure concerns, at first place, the way end users participate in the deployment and evolution of their infrastructure. It gives rise, however, to a number of issues, addressing their organization and management, legal status and recognition from public authorities, and overall sustainability. A necessary, but not sufficient, condition for the latter is the sustained participation in the network of the whole set of their shareholders, including the volunteers that lead the initiatives; the local communities under the coverage of these CNs; commercial entities that could offer services over them. Equally important is the multi-level support of public administrations with funding capacity and/or regulation authority.

In this report, we have first reviewed for each CN stakeholder different political causes, cultural and social ideals, as well as economic aspirations that can stand as motives for their participation in CNs. We have then proceeded with incentive mechanisms, *i.e.*, processes, measures, tools that have been put in practice, or been proposed in more theoretical level, in existing CNs. The aim of these mechanisms is to properly respond to the original participation motives, but also mitigate risks and phenomena that may end up canceling them.

We have finished this first edition of the deliverable on "Incentives for Participation and Active Collaboration in CNS" with a more detailed look at the grid of motives and incentive mechanisms in two CNs: the guifi.net and the Sarantaporo.gr CNs. These two networks will be central in our studies on incentives during the Y2 of the project. Beyond the development work on local applications (Cloudy for guifi.net and CommonTasker for Sarantaporo.gr) in WP3, the theoretical work on incentives in the task 2.2 of the project will focus on two main questions: the sustainability of the guifi.net compensation system, which is the main tool for incentivizing the participation of commercial entities in the CN; and the exportability of this model to the newer and promising Sarantaporo.gr CN.

More specifically, part of the work in Y2 will be devoted to analyzing the incentive mechanisms that guifi.net has put in place. As said before, this network presents one very distinct approach to making CNs sustainable by involving commercial service providers in the network. These providers are motivated to cooperate in developing the network infrastructure and increasing the potential customer base for their services, while they also compete for providing services to these customers. This combination of cooperation (at network infrastructure level) and competition (at service level) appears to be a fundamental ingredient of the success of guifi.net so far. It is not clear to what extent this model scales with the size of the CN, the number of competing providers over the CN, but also the number of competing commercial networks. We intend to undertake a theoretical analysis of the model involving game theoretic tools (for the strategies that professionals employ over the CN) and reciprocity theories regarding the way the network coverage grows with the addition of new users. The aim will be to provide some deeper insights to the otherwise heuristic incentive mechanisms of guifi.net, and amend them or enhance them where possible to increase their efficiency.

The interest in the guifi.net business model is largely related to its potential for replication in other CNs. Yet this is not a straightforward task for a number of reasons. First, as it should be clear from this document, the motivation of the volunteers and the users behind these initiatives can be very different, not least due to geographical factors (urban *vs.* rural areas). Second, the community sizes

are different. This is something with both positive and negative implications. On the one hand, small communities tend to be tighter, sharing stronger social links and more similar interests, as can be evidenced in the Sarantaporo.gr case (ref. section 4.3). On the other hand, they might be poorer in terms of skills and resources (time, funds) than larger communities.

Therefore, the work in Task 2.2 will also seek to propose incentive mechanisms that can address the sustainability challenge for the Sarantaporo.gr network. This is going to be pursued through different directions. One of them is trying to import elements from the guifi.net model such as the involvement of professionals in the network and the provision of commercial services over it. In the workshop that was organized in the area of Sarantaporo in 26-27 November 2016, we had the chance to identify potential such services (focusing on precision agriculture) and identify real interest of commercial service providers [67]. In T2.2, we will design incentives to accommodate the particular services that are of interest in this case, taking into account the particularities of the Sarantaporo.gr network such as the ownership of network nodes and network connectivity alternatives that are available in the area.

A second, related direction, is through the launch of a mobile application over the CN that realizes mobile crowdsourcing and sharing economy practices. The role of the app is to both address the needs of the local communities and strengthen the cooperation and trust among their members. The development of the application is carried out in WP3. In T2.2, we will analyze incentives that can be embedded in the application to maximize its use, and through that, the use of the CN. To this end, there will be synergies with T2.4 on the use of community currencies as such an incentive mechanisms (ref. section 3.1.3)

Bibliography

[1] L. Navarro, R. Baig, F. Freitag, E. Dimogerontakis, F. Treguer, M. Dulong de Rosnay, L. Maccari, P. Micholia, and P. Antoniadis, "Report on the Existing CNs and their Organization (v2)," netCommons Deliverable D1.2, Sept. 2016. http://netcommons.eu/?q=content/report-existing-cns-and-their-organization-v2

[2] R. Baig, R. Roca, F. Freitag, and L. Navarro, "guifi.net, a crowdsourced network infrastructure held in common," *Computer Networks*, vol. 90, pp. 150 – 165, 2015. http://dx.doi.org/10.1016/j.comnet.2015.07.009

[3] C. Fuchs, M. Michalis, and D. Boucas, "The Multiple Aspects of Politics of Sustainability in Community Networks: Definitions, Challenges, and Countermeasures (v1)," netCommons Deliverable D2.1, June 2016. http://netcommons.eu/?q=content/multiple-aspects-politics-and-sustainability-cns-definitions-challenges-and-countermeasures

[4] M. Gurstein, "What is community informatics (and why does it matter)?" *CoRR*, vol. abs/0712.3220, 2007. http://arxiv.org/abs/0712.3220

[5] D. Schuler, *New Community Networks: Wired for Change*. New York, NY, USA: ACM Press/Addison-Wesley Publishing Co., 1996.

[6] M. Bina and G. M. Giaglis, "A motivation and effort model for members of wireless communities." in *ECIS*, 2006, pp. 618–625.

[7] C. Fuchs, M. Michalis, and D. Boucas, "The Multiple Aspects of Politics of Sustainability in Community Networks: Definitions, Challenges, and Countermeasures (v2)," netCommons Deliverable D2.2, Jan. 2017. http://netcommons.eu/?q=content/multiple-aspects-politics-and-sustainability-cns-definitions-challenges-and-countermeasure-0

[8] "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary Educational Psychology*, vol. 25, no. 1, pp. 54 – 67, 2000. http://dx.doi.org/10.1006/ceps.1999.1020

[9] E. Lawrence, M. Bina, G. Culjak, and T. El-Kiki, "Wireless community networks: Public assets for 21st century society," in *Fourth International Conference on Information Technology (ITNG'07)*, 2007.

[10] P. Antoniadis, B. L. Grand, A. Satsiou, L. Tassiulas, R. L. Aguiar, J. P. Barraca, and S. Sargento, "Community building over neighborhood wireless mesh networks," *IEEE Technology and Society Magazine*, vol. 27, no. 1, pp. 48–56, Spring 2008.

[11] M. Bina and G. M. Giaglis, "Unwired collective action: Motivations of wireless community participants," in *2006 International Conference on Mobile Business*, June 2006, pp. 31–31.

[12] J. Avonts, B. Braem, and C. Blondia, "A questionnaire based examination of community networks," in *2013 IEEE 9th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, Oct 2013, pp. 8–15.

[13] Jason, "Sustaining Community – Incentive Mechanisms in Online Systems: Final Report of the Group 2005 Workshop," *Group*, 2005.

[14] G. Klissiaris, "The digital techology as a growth factor of remote rural areas - the case of sarantaporo.gr non-profit organization," Department of Marketing & Communication, AUEB, 2016.

[15] S. Crabu, F. Giovanella, L. Maccari, and P. Magaudda, "Hacktivism, infrastructures and legal frameworks in community networks: The italian case of ninux.org," *Journal of Peer Production, Special issue on Alternative Internets*, no. 9, 2016. http://peerproduction.net/issues/issue-9-alternative-internets/peer-reviewed-papers/ninux-org/

[16] R. Baig, R. Roca, F. Freitag, and L. Navarro, "Guifi.net, a crowdsourced network infrastructure held in common," *Comput. Netw.*, vol. 90, no. C, pp. 150–165, Oct. 2015. http://dx.doi.org/10.1016/j.comnet.2015.07.009

[17] J. Barcelo, B. Bellalta, R. Baig, R. Roca, A. Domingo, L. Sanabria, C. Cano, and M. Oliver, "Bottom-up broadband initiatives in the commons for europe project," *CoRR*, vol. abs/1207.1031, 2012. http://arxiv.org/abs/1207.1031

[18] C. Aichele, R. Flickenger, C. Fonda, J. Forster, I. Howard, T. Krag, M. Zennaro *et al.*, "Wireless networking in the developing world," 2006.

[19] M. Pérez, P. Boronat, J. A. Gil, and A. Pont, *guifi.net: A Bottom-up Initiative for Building Free Telecommunication Infrastructure*. Cham: Springer International Publishing, 2016, pp. 144–155. http://dx.doi.org/10.1007/978-3-319-44447-5_14

[20] J. Barcelo, "Bottom-up Broadband: Free Software Philosophy Applied to Networking Initiatives," 2014. http://jaume.barcelo.cc/paper/2014/07/14/Bottom-up-Broadband-Free-Software-Philosophy-Applied-to-Networking-Initiatives/

[21] M. Oliver, J. Zuidweg, and M. Batikas, "Wireless commons against the digital divide," in *2010 IEEE International Symposium on Technology and Society*, June 2010, pp. 457–465.

[22] M. Dischinger, M. Marcon, S. Guha, K. P. Gummadi, R. Mahajan, and S. Saroiu, "Glasnost: Enabling end users to detect traffic differentiation," in *Proceedings of the 7th USENIX Conference on Networked Systems Design and Implementation*, ser. NSDI'10. Berkeley, CA, USA: USENIX Association, 2010, pp. 27–27. http://dl.acm.org/citation.cfm?id=1855711.1855738

[23] D. Miorandi, I. Carreras, E. Gregori, I. Graham, and J. Stewart, "Measuring net neutrality in mobile internet: Towards a crowdsensing-based citizen observatory," in *2013 IEEE International Conference on Communications Workshops (ICC)*, June 2013, pp. 199–203.

[24] M. Dischinger, A. Mislove, A. Haeberlen, and K. P. Gummadi, "Detecting bittorrent blocking," in *Proceedings of the 8th ACM SIGCOMM Conference on Internet Measurement*, ser. IMC '08, 2008, pp. 3–8. http://doi.acm.org/10.1145/1452520.1452523

[25] E. Ostrom, *Governing the commons: the evolution of institutions for collective action*. Cambridge University Press, Nov. 1990.

[26] D. Vega, R. Meseguer, and F. Freitag, *Analysis of the Social Effort in Multiplex Participatory Networks*. Cham: Springer International Publishing, 2014, pp. 67–79. http://dx.doi.org/10.1007/978-3-319-14609-6_5

[27] C. Szabó, Z. Horváth, and K. Farkas, "Wireless community networks: motivations, design and business models," in *3rd ICST Int. Conf. on Wireless internet*, 2007, p. 23.

[28] L. F. Pedraza, A. Cepeda Ruiz, and D. Ballesteros, "Community wireless network development in ciudad bolívar," *Tecnura*, vol. 17, no. 36, pp. 10–20, 2013.

[29] P. Antoniadis and B. L. Grand, "Incentives for resource sharing in self-organized communities: From economics to social psychology," in *Digital Information Management, 2007. ICDIM '07. 2nd International Conference on*, vol. 2, Oct 2007, pp. 756–761.

[30] D. W. Mcdonald, "Social issues in self-provisioned metropolitan area networks," in *McDonald,*

Workshop Paper, Mobile Ad-Hoc Collaboration, ACM 2002 Conference on Human Factors in Computing Systems, 2002.

[31] R. Sofia, A. Bogliolo, F. Sivrikaya, H. Zhu, O. Marce, and D. Valerdi, "User-centric networking and services: part 2 [guest editorial]," *IEEE Communications Magazine*, vol. 52, no. 12, pp. 16–16, December 2014.

[32] A. Lertsinsrubtavee, L. Wang, A. Sathiaseelan, J. Crowcroft, N. Weshsuwannarugs, A. Tunpan, and K. Kanchanasut, "Understanding internet usage and network locality in a rural community wireless mesh network," in *Proceedings of the Asian Internet Engineering Conference*, ser. AINTEC '15. New York, NY, USA: ACM, 2015, pp. 17–24. http://doi.acm.org/10.1145/2837030.2837033

[33] D. L. Johnson, E. M. Belding, K. Almeroth, and G. van Stam, "Internet usage and performance analysis of a rural wireless network in macha, zambia," in *Proceedings of the 4th ACM Workshop on Networked Systems for Developing Regions*, ser. NSDR '10. New York, NY, USA: ACM, 2010, pp. 7:1–7:6. http://doi.acm.org/10.1145/1836001.1836008

[34] M. Korn, "Hybrid wireless networks for neighborhood communities," in *Workshop on Residents' Democratic Engagement in Public Housing and Urban Areas at Aarhus 2015: Critical Alternatives*, Aarhus, Denmark, Aug. 2015.

[35] A. M. Khan, L. Navarro, L. Sharifi, and L. Veiga, "Clouds of small things: Provisioning infrastructure-as-a-service from within community networks," in *2013 IEEE 9th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, Oct 2013, pp. 16–21.

[36] R. Baig, L. Dalmau, R. Roca, L. Navarro, F. Freitag, and A. Sathiaseelan, "Making community networks economically sustainable, the guifi.net experience," in *Proceedings of the 2016 Workshop on Global Access to the Internet for All*, ser. GAIA '16. New York, NY, USA: ACM, 2016, pp. 31–36. http://doi.acm.org/2940157.2940163

[37] G. Gheorghe, R. Lo Cigno, and A. Montresor, "Security and privacy issues in P2P streaming systems: A survey," *Peer-to-Peer Networking and Applications*, vol. 4, no. 2, pp. 75–91, 2011. http://dx.doi.org/10.1007/s12083-010-0070-6

[38] G. Ciccarelli and R. Lo Cigno, "Collusion in Peer-to-Peer Systems," *Computer Networks, Elsevier*, vol. 55, no. 15, pp. 3517–3532, Oct. 2011. http://dx.doi.org/10.1016/j.comnet.2011.06.028

[39] M. A. Nowak, "Five rules for the evolution of cooperation," *science*, vol. 314, no. 5805, pp. 1560–1563, 2006.

[40] E. C. Efstathiou, P. A. Frangoudis, and G. C. Polyzos, "Stimulating participation in wireless community networks," in *Proceedings IEEE INFOCOM 2006. 25TH IEEE International Conference on Computer Communications*, April 2006, pp. 1–13.

[41] E. C. Efstathiou, F. A. Elianos, P. A. Frangoudis, V. P. Kemerlis, D. C. Paraskevaidis, G. C. Polyzos, and E. C. Stefanis, "Practical incentive techniques for wireless community networks," in *4th International Conference on Mobile Systems, Applications, and Services (MobiSys 2006) Demo Session, Uppsala, Sweden*. Citeseer, 2006.

[42] U. C. Buyuksahin, A. M. Khan, and F. Freitag, "Support service for reciprocal computational resource sharing in wireless community networks," in *2013 IEEE 14th International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM)*, June 2013, pp. 1–6.

[43] Ü. Ç. Büyükşahin, "On incentive mechanisms for resource sharing in community clouds," Ph.D. dissertation, Universitat Politécnica de Catalunya, 2013.

[44] D. Vega, R. Messeguer, S. F. Ochoa, J. A. Pino, F. Freitag, E. Medina, and D. Royo, "Sharing hardware resources in heterogeneous computer-supported collaboration scenarios," *Integr. Comput.-Aided Eng.*, vol. 20, no. 1, pp. 59–77, Jan. 2013. http://dx.doi.org/10.3233/ICA-120419

[45] S. Buchegger, J. Mundinger, and J. Y. L. Boudec, "Reputation systems for self-organized networks," *IEEE Technology and Society Magazine*, vol. 27, no. 1, pp. 41–47, Spring 2008.

[46] A. Satsiou and L. Tassiulas, "A trust-based exchange framework for multiple services in p2p systems," in *Seventh IEEE International Conference on Peer-to-Peer Computing (P2P 2007)*, Sept 2007, pp. 45–52.

[47] S. Buchegger and J.-Y. Le Boudec, "Performance analysis of the confidant protocol," in *Proceedings of the 3rd ACM International Symposium on Mobile Ad Hoc Networking &Amp; Computing*, ser. MobiHoc '02. New York, NY, USA: ACM, 2002, pp. 226–236. http://doi.acm.org/10.1145/513800.513828

[48] P. Michiardi and R. Molva, "Core: A collaborative reputation mechanism to enforce node cooperation in mobile ad hoc networks," in *Proceedings of the IFIP TC6/TC11 Sixth Joint Working Conference on Communications and Multimedia Security: Advanced Communications and Multimedia Security*. Deventer, The Netherlands, The Netherlands: Kluwer, B.V., 2002, pp. 107–121. http://dl.acm.org/citation.cfm?id=647802.737297

[49] K. Panchanathan and R. Boyd, "Indirect reciprocity can stabilize cooperation without the second-order free rider problem," *Nature*, vol. 432, no. 7016, pp. 499–502, 11 2004.

[50] F. Martignon, S. Paris, and A. Capone, "A framework for detecting selfish misbehavior in wireless mesh community networks," in *Proceedings of the 5th ACM Symposium on QoS and Security for Wireless and Mobile Networks*, ser. Q2SWinet '09, 2009, pp. 65–72. http://doi.acm.org/10.1145/1641944.1641958

[51] R. Mahajan, M. Rodrig, D. Wetherall, and J. Zahorjan, "Sustaining cooperation in multi-hop wireless networks," in *Proceedings of the 2Nd Conference on Symposium on Networked Systems Design & Implementation - Volume 2*, ser. NSDI'05. Berkeley, CA, USA: USENIX Association, 2005, pp. 231–244. http://dl.acm.org/citation.cfm?id=1251203.1251220

[52] P. Antoniadis, J. Martignoni, and L. Navarro, "Economic Sustainability of CNs (v1) Introducing Community Currencies," netCommons deliverable D2.4, Dec. 2016. http://netcommons.eu/?q=content/economic-sustainability-cns-v1

[53] M. Feldman, K. Lai, I. Stoica, and J. Chuang, "Robust incentive techniques for peer-to-peer networks," in *Proceedings of the 5th ACM Conference on Electronic Commerce*, ser. EC '04. New York, NY, USA: ACM, 2004, pp. 102–111. http://doi.acm.org/10.1145/988772.988788

[54] M. Felegyhazi, J. P. Hubaux, and L. Buttyan, "Nash equilibria of packet forwarding strategies in wireless ad hoc networks," *IEEE Transactions on Mobile Computing*, vol. 5, no. 5, pp. 463–476, May 2006.

[55] G. Biczók, L. Toka, A. Gulyás, T. A. Trinh, and A. Vidács, "Incentivizing the global wireless village," *Comput. Netw.*, vol. 55, no. 2, pp. 439–456, Feb. 2011. http://dx.doi.org/10.1016/j.comnet.2010.08.014

[56] W. Wu, J. C. S. Lui, and R. T. B. Ma, "A game theoretic analysis on incentive mechanisms for wireless ad hoc vod systems," in *2012 10th International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt)*, May 2012, pp. 177–184.

[57] S. Zhong, J. Chen, and Y. R. Yang, "Sprite: A simple, cheat-proof, credit-based system for mobile ad-hoc networks," in *INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies*, vol. 3. IEEE, 2003, pp. 1987–1997.

[58] S. Zhong, L. E. Li, Y. G. Liu, and Y. R. Yang, "On designing incentive-compatible routing and forwarding protocols in wireless ad-hoc networks," *Wireless Networks*, vol. 13, no. 6, pp. 799–816, 2007. http://dx.doi.org/10.1007/s11276-006-9855-1

[59] A. Marinos and G. Briscoe, "Community cloud computing," in *Proceedings of the 1st International Conference on Cloud Computing*, ser. CloudCom '09. Berlin, Heidelberg: Springer-Verlag, 2009, pp. 472–484. http://dx.doi.org/10.1007/978-3-642-10665-1_43

[60] E. Efstathiou, F. Elianos, P. Frangoudis, V. Kemerlis, D. Paraskevaidis, G. Polyzos, and E. Stefanis, "Building secure media applications over wireless community networks," in *13th HP Openview University Association (HPOVUA) Workshop, Nice, France (May 2006)*, 2006.

[61] P. A. Frangoudis and G. C. Polyzos, "On the performance of secure user-centric voip communication," *Computer Networks*, vol. 70, pp. 330 – 344, 2014. http://www.sciencedirect.com/science/article/pii/S1389128614002400

[62] P. Frangoudis and G. Polyzos, "Security and performance challenges for user-centric wireless networking," *IEEE Communications Magazine*, vol. 52, no. 12, pp. 48–55, December 2014.

[63] T. Luo and C. K. Tham, "Fairness and social welfare in incentivizing participatory sensing," in *Sensor, Mesh and Ad Hoc Communications and Networks (SECON), 2012 9th Annual IEEE Communications Society Conference on*, June 2012, pp. 425–433.

[64] M. Selimi, A. M. Khan, E. Dimogerontakis, F. Freitag, and R. P. Centelles, "Cloud services in the guifi.net community network," *Comput. Netw.*, vol. 93, no. P2, pp. 373–388, Dec. 2015. http://dx.doi.org/10.1016/j.comnet.2015.09.007

[65] N. Facchi, F. Freitag, L. Maccari, P. Micholia, and F. Zanini, "Release of All Open Source Software for all Applications (v1)," netCommons Deliverable D3.2, Dec. 2016. http://netcommons.eu/?q=content/release-new-open-source-software-all-applications-v1

[66] A. Abdelaal, *Social and economic effects of community wireless networks and infrastructures*. IGI Global, 2013.

[67] P. Antoniadis, I. Apostol, P. Micholia, G. Klissiaris, V. Chryssos, and M. Karaliopoulos, "Multi-Disciplinary Methodology for Applications Design for CNs, including Design Guidelines and Adoption Facilitation (v1)," netCommons Deliverable D3.1, Jan. 2017. http://netcommons.eu/?q=content/multi-disciplinary-methodology-applications-design-cns-including-design-guidelines-and

The netCommons project

February 24, 2017

netCommons-D2.3-1.0

Horizon 2020