On the Sustainability of Community Clouds in guifi.net

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Abstract. The Internet and cloud services are key enablers for participation in society. The need for Internet access in areas underserved by commercial telecom operators has often been a motivation to develop community networks. Many examples around the world show successful cooperative developments of open, participatory local networking infrastructures. Such collaborative models have not yet been applied to local cloud computing resources and services. In this paper, we elaborate on the sustainability model of the guifi.net community network as a basis for cloud-based infrastructures and services in communities. We first look at the elements of guifi.net, which support the sustainability and growth of the networking infrastructure. We then discuss their application to cloud-based services within the network and come up with a framework of tools and components for community cloud resources and services. Finally, we assess the current status of the experimental community cloud in guifi.net, where some of the proposed tools are already operational.

Keywords: cloud computing, community networks, community clouds, common-pool resource

1 Introduction

All citizens and organizations should be able to participate and benefit in the digital society, with the Internet and cloud services as key enablers. The need for Internet access in areas which were left unattended by commercial telecom operators has often been a motivation to develop community-driven local network infrastructures. Community networks, also known as bottom-up-broadband networks, consist of a communication infrastructure in which local communities of citizens build, operate and own open IP-based networks. Hundreds of community networks operate across the globe, in rural and urban, rich and poor areas. In Europe, several community networks have been operating for more than ten years and have surpassed a thousand of nodes[3]. The participants, as volunteers, enterprises, public and private organisations share resources, being these not only networking hardware, but also time, effort and knowledge, which

[3] Freifunk: `http://freifunk.net` in Germany, over 3,000; AWMN: `http://awmn.gr` in Greece, over 2,000; and guifi.net: `http://guifi.net` in Spain, over 29,000.

are required to develop and maintain the network infrastructure used by the community. However these community networks incorporate many local services of common interest that require shared computing and storage resources. These shared computing resources, combined with Internet access, bring to users new possibilities for digital services, beyond the generic services offered mainly by global cloud service providers in the Internet. The potential lies in the application of the community cloud concept [1] to communities of citizens. In its generic form, a community cloud refers to a cloud deployment model in which a cloud infrastructure is built and provisioned for an exclusive use by a specific community of consumers with shared concerns and interests, owned and managed by the community or by a third party or a combination thereof [2]. While commercial community cloud solutions are a reality nowadays in several application areas such as in the financial, governmental and health sector, fulfilling community-specific requirements (e.g. security, performance, local content), citizen community clouds are not yet available today.

In this paper, we argue that a community network cloud, a cloud formed by community-owned local computing and communication resources able to provide services of local interest, can emerge and be sustainable if the appropriate tools and mechanisms are in place to govern the collective action of the community.

We elaborate a proposal for such a cloud for communities of citizens modelled after the model of guifi.net community network, which is the most successful and developed case among these networks in terms of size of the network, number and variety of participants, and complexity of the ecosystem.

The main contributions of this paper are the following: *a*) A revision of the model that is applied in the guifi.net community network for the network sustainability. *b*) Identification of specific issues concerning the sustainability of citizen community clouds. *c*) A framework for establishing and maintaining community cloud infrastructures and services based on the guifi.net model. *d*) An analysis of the current cloud infrastructure in guifi.net and assessment.

We elaborate our contributions as follows: In section 2 we describe the guifi.net ecosystem for the access, operation and governance of the network infrastructure. We identify in section 3 specific issues of cloud computing for the adoption of this sustainability model. In section 4, we propose a framework containing tools and components for cloud-based service provision by a community. In section 5 we describe how the framework has been implemented so far in guifi.net and analyze several performance indicators. In section 6 we conclude outlining our findings and future work.

2 Elements of the guifi.net Ecosystem

2.1 Network infrastructure as a Common-Pool Resource

guifi.net is managed as a *Common-Pool Resource* (CPR) [3], being the network infrastructure the core resource. Holding the infrastructure as a commons has some immediate effects such as the avoidance of the multiplicity of infrastructure

because all participants operate on the same, and the increase of efficiency of the infrastructure in terms of costs saving and ease of participation. The CPR, i.e. the guifi.net infrastructure, grows by each new network segment which the participants deploy to reach the network or to improve it, and the reward for the contributors is the network connectivity that participants get [4].

For commercial services, guifi.net as a CPR translates into a reduced entry barrier for starting business ventures, since the network infrastructure is available for usage to everyone in the community, both to individual and professional users, and participants can benefit from pooling, with lower individual investments since resources are shared. The knowledge about the network is open and the network is neutral: no barriers that artificially limit the scope of service creations.

Nonetheless, community networks, as any other CPR, are fragile. More precisely, being non-excludable they are congestion prone, because connectivity is subtractable, and therefore subject to the free riding problem. Thus, efficient and effective governance tools are needed to protect the core resource from depletion [3], that is to say, to protect it from the *Tragedy of the commons* [5].

2.2 Stakeholders

There are four main stakeholders in guifi.net. The *volunteers*, the initiators of the project, due to their lack of economic interests, are responsible for the operation of the tools and mechanisms of governance and oversight. The *professionals* bring in quality of service, and their *customers* bring the resources which make the ecosystem economically sustainable. *Public administrations* are responsible for regulating the interactions between the network deployment and operation, and public goods, such as public domain occupation. All participants that extract connectivity must contribute infrastructure, directly or indirectly, and can participate in the knowledge creation process.

guifi.net is a success case for the coexistence of voluntarism and a well-established professional activity operating on the same CPR, i.e the communication network. Governance tools implemented in guifi.net play a critical role in keeping that balance. This is critical for the sustainability of the project, because, although the economic sustainability is mostly based on the revenue generated by professional activity, the governance and the harmonisation of the ecosystem is mostly carried out by volunteers.

2.3 Communication and coordination tools

The technical skills among most participants, its distribution across the territory and the need to coordinate decisions to keep the network infrastructure operational has resulted in the development of many tools to facilitate communication and coordination among participants and the components of the infrastructure.

Software tools for network management and provisioning: The community of guifi.net has developed a set of software tools to ease the design, deployment, management and operation of the network in a self-provisioning

style and supporting crowd-sourced efforts by members of the community given the intrinsic inter-dependence in the computer and social network. Most of them are integrated in the guifi.net web site.

Communication tools: The most significant tools for communication among the participants are the *Mailing lists* with global, territorial and thematic scope, open by default. *Social Media* also open by default with a few exceptions to protect sensitive information. *Face to face meetings* play a key role in strengthening social relationships and sharing initiatives and knowledge.

2.4 Participation framework

Participation in the community is organized by agreements: the community license shared by all participants, and a set of bilateral collaboration agreements between the entity representing the community and other organisations such as professionals or public administrations.

Network Commons License: The NCL[4] is the license that every guifi.net participant must subscribe, developed and approved through a long standing open deliberation process. Its preamble sets the fundamental principles and the articles precisely establish the participants rights and duties to join, use, understand, offer services as long as respecting and not interfering with the operation of the network, the rights of other users, and the neutrality of the network to contents and services. It is written to be enforceable under the Spanish legislation, as legal certainty is essential to stimulate participation and investment, which in turn, is at the base of any economic activity and therefore its sustainability.

Reference Authority: The guifi.net Foundation (*Fundació Privada per a la Xarxa, Lliure i Neutral guifi.net*) is a reference organisation founded by the guifi.net community that gives a legal identity to the community. As such, it plays a vital role for the coordination of the guifi.net ecosystem. Its foundational mission is to protect and promote the network held in commons.

Collaboration agreements: aimed at strengthening the legal certainty derived from the NCL. These agreements result from the experience of many specific agreements over the years. The main set of agreements are with:

Professionals Any professional willing to carry out economic activities involving guifi.net infrastructure must sign a professional agreement with the Foundation. As part of it, the professional must state its level of commitment to the commons. There are tree options regarding contribution of his deployed infrastructure to the commons: *type A*, all of it, *type B*, a part of it only, and *type C*, nothing (that professional uses what is available but does not contribute at all). The agreement implies the acceptance of a set of Service Level Agreements (SLAs) aiming at facilitate the coexistence among the professionals. Once the agreement is signed, the professional is included in the economic compensations system.

Third parties The Foundation also establishes agreements with third parties such as public administrations, private companies or universities.

[4] `http://guifi.net/en/FONNC`.

2.5 Governance tools

These are socio-economic tools developed by the community and managed by the Foundation to keep the infrastructure and the community operational and balanced. The pillar of this collaboration is a system with several type of agreements based on the level of commitment with the commons and an economic compensation system for investments and resource consumption.

Conflicts resolution system: A systematic and clear procedure for resolution of conflicts with a scale of graduated sanctions has been developed. It consists of three stages, conciliation, mediation and arbitration, all of them driven by a lawyer.

Economic compensations system: Developed and implemented to compensate imbalance between investment in the commons infrastructure and network usage among professionals. Expenditures declared by the professionals are periodically cleared according to the network usage. The Foundation computes and manages the billing system.

2.6 Implementation and impact

Currently, at the physical level, the guifi.net infrastructure combines several technologies: wireless and optical fibre are the most common. As of July 2015, guifi.net has a total of 45,650 nodes, 29,200 of them declared as operational. The 10 Gbps guifi.net optical backbone has three Internet uplink carriers. More than 400 internal application servers are announced.

The participation among stakeholders is quite diverse, with an estimate of 13,500 registered members, nine SME participating in the economic compensations system, 270 subscribers in the mailing list for professionals, and more than a hundred of councils actively collaborating with guifi.net.

Recent statistics about network penetration in households[5] [6] show the Catalan county with the best results, and the only one above the EU average, is Osona, where guifi.net was born. Other counties with high guifi.net presence shown similar results contrasting with similar counties where guifi.net presence is irrelevant.

Currently, the main sources of economic activity in guifi.net are, on the one hand, those related to the infrastructure deployment and maintenance, and on the other hand, services delivered over the network. Although Internet access is still the most popular service, others such as VoIP, remote maintenance or backups have also been offered for a long time. New services such as video streaming and video on-demand are appearing, especially in the areas served by optical fibre. The growing trend toward local services being offered in the network infrastructure to a growing user base brings the need to a shared pool of configurable computing resources and platform services to manage that computing infrastructure.

[5] Catalan Statistics Institute (IDESCAT) `http://www.idescat.cat`

3 The sustainability of community cloud computing

The organisational structure of the guifi.net network infrastructure, described in the previous section, follows the principles of long-enduring CPR institutions. However, when considering a shared pool of configurable computing resources and services, there are specific aspects to discuss in community clouds.

A CPR typically consists of a core resource which provides a limited quantity of extractable fringe units. In the case of a community cloud, as the core resource is nurtured by diverse contributions of networking, computing and service elements the participants deploy to expand or improve it, and the fringe unit is the service they obtain.

The following differences of cloud resources compared to the network infrastructure have been identified:

Building elements: For a community cloud, the building elements are more diverse than in the underlying network since, in addition to the physical level where host devices (*servers*) provide computing and storage services and the network provides connectivity, the cloud software stack (IaaS, PaaS and SaaS) are also building elements that provide diverse additional services.

Inter-dependency among resources: The resulting asset at the network level is a primary infrastructure, that is to say, it has no inherent dependencies to other infrastructures. This is not the case for the cloud, which inherently depends on network connectivity for the interaction among building elements and users. In addition there are inter-dependencies among physical resources with services and among different services. Some resources or services could be more critical or demanded than others. The consequences of the deployment of an infrastructure with such dependencies must be studied not only from the viewpoint of usage/demand/traffic on a specific class of resource, but also from a more systemic viewpoint to answer questions about the complexity of interaction and balance across classes of cloud resources, resource bundles required in services, congestion management and fairness, influence with related infrastructures such as the underlying network, the power grid, the environment, or the socio-economic community of users and organisations around.

Roles and balance between professionals and volunteers: We can expect a mix of voluntary contributions of networking and computing resources, even cloud services provided in a best-effort (or peer-to-peer) manner, together with professionally operated resources run by local or global providers, perhaps at a higher cost but also at a higher scale and with service-level commitments. As with the network, the community structure can incorporate both volunteers and professionals or SMEs, and in fact, create the opportunity for local entrepreneurs to offer tailored cloud-based services to address community needs, and develop an inclusive socio-economic ecosystem for local development. The guifi.net

participation framework with the community license, the authority of its foundation, the collaboration agreements, conflict resolution and economic compensations system can be directly implemented to regulate and promote this.

Infrastructure vs. services division It seems that the rule applied for the network infrastructure level, "the guifi.net community takes care of the infrastructure as a CPR, the content is left up to the users" (considering content as pure usage and therefore external to the CPR, can also be applied to the cloud level, but the criteria to determine what must be considered external (as content) and what is considered infrastructure must be set. This boundary between internal and external services also determines how hybrid clouds should be considered.

4 A framework for cloud-based services in guifi.net

As in the case of the network infrastructure, the implementation of the CPR at the cloud level requires effective rules and tools. The design principles identified in [3] for the institutions to govern successfully collective action for a CPR inspired the tools which are presented in this section. We determine and materialize in the following the components and tools needed to implement a community cloud as a CPR.

4.1 Community Cloud infrastructure as a Common-Pool Resource

The fundamental principles of guifi.net apply to a community cloud, defined to be fully inclusive, that revolve around i) the openness of access (usage) of the infrastructure, and ii) the openness of participation (construction, operation, governance) in the development of the infrastructure and its community. The application of these fundamental principles result in a community cloud resource and service infrastructure that is a *collective good*, *socially produced*, and governed as a *common-pool resource*.

The reasons that apply at network level to the conception of the contributed infrastructure as a CPR, e.g. standardisation of resource management, interoperability of individual contributed resources, need for ease of contribution by users, seem also to stand for citizen community clouds. With a set of essential IaaS and PaaS cloud services given as a CPR, enhanced and aggregated SaaS services may be built upon them and offered on a cost-sharing or a for-profit model. Previous volunteer computing proposals, e.g. [7], often addressed the trading of virtual machines (VMs) corresponding to the cloud IaaS, upon which users would deploy their services. VMs and basic cloud services are part of the CPR and therefore subject to allocation under the community license, the economic compensations and conflict resolution system. However, this scheme would enable service trading already at the level of complex services built upon this CPR. Similar to how the network

CPR reduces the entry barrier (through network transparency, neutrality, cost sharing, resulting in reduced CAPEX and OPEX cost) and enables the market niche of proximity services, a cloud infrastructure held as a CPR might contribute to make it more accessible for SMEs.

4.2 Stakeholders

The coexistence of volunteer and for-profit participants, already happening at the network level, is desirable to be extended to the cloud level. Thus, the concept of the resources needed to build the cloud (the hardware and the software) as a CPR will establish a framework for contribution and collaboration between volunteers and for-profit professionals, similarly to what has been built at the network level.

4.3 Computing, coordination and communication tools

As with the network infrastructure, a set of software tools and services are required to ease the tasks of deploying the components of the infrastructure and coordinating its operation and usage.

Cloud Access Points (CAP): In order to facilitate the adoption of the required software components, a GNU/Linux software distribution containing all of them has been developed. The distribution, named *Cloudy*, is delivered as a standalone version and as a container to be installed in a users's computer device. Cloud participants interact with it through a Web-GUI.

Cloud Resource Devices: Computing resources are also provided by a set of Resource Devices (RD), a resource aggregate. These are network-attached low-power computers deployed anywhere in the network, dedicated to provide computing and storage resources in the form of virtual machines implemented as Linux Containers with access control, resource isolation and management capabilities to grant a trusted remote user with full access to the processing, storage and network resources allocated to a given container. RDs are based on the OpenWRT GNU/Linux distribution extended with a remote control (REST API) service that can manage the life-cycle of multiple containers running concurrently in the same host. We call each of these containers a *sliver* and the set of slivers on diverse RDs belonging to a service are a *slice*.

Infrastructure as a Service (IaaS)

Virtual machines: A service for allocating and managing virtual machines (VMs) is a key enabler of cloud uptake. In Cloudy Cloud Access Points the service is implemented using OpenVZ technology through its Web Panel, and in Cloud Resource Devices this is implemented through the Resource Controller Web Panel or its REST API.

Platform as a Service (PaaS)

Distributed announcement and discovery of services (DADS): In a peer-production context it is essential to have an effective mechanism to find out the services available automatically. DADS uses the Serf gossip protocol for exchanging information about the active services available, and has been developed as a core component of Cloudy. The discovered services are presented to the user grouped by categories and can be sorted according to several metrics, including locality.

Authentication service: This service provides user authentication by a recognised independent third party. The concept results from the evolution of the solution to authentication needs of the guifi.net federated proxy system. Currently, it is implemented using LDAP in a redundant master-slave architecture hosted and operated by the guifi.net Foundation.

Software as a Service (SaaS)

guifi.net services: The three main services in guifi.net have been integrated in Cloudy:

DNS Service to participate in the guifi.net DNS system for the resolution of internal addresses (RFC1918). Implemented with BIND.

Network monitoring instance to contribute to the network monitoring system. It is implemented using SNMP feeding RRDtool buffer rings.

Web proxy as part of hundreds of Internet gateways contributed by volunteers. That way any validated user can access any of the federated web proxies for Internet service. The service is base on the Squid proxy software.

Third-party services: The following third-party services are currently integrated in Cloudy:

syncthing A decentralised cloud storage system with cryptographic features which gives full control to the users over where their data is replicated.

PeerStreamer A peer-to-peer media streaming framework with a streaming engine for the efficient distribution of media streams, a source application for the creation of channels and a player applications to visualize the streams.

Tahoe-LAFS A fault-tolerant encrypted decentralized cloud storage system which distributes user data across multiple servers in replicated data chuncks. Even if some of the servers fail or are taken over by an attacker, the entire file store continues to function correctly while preserving user's privacy and security.

WebDAV server A set of extensions to the HTTP protocol which allows users to collaboratively edit and manage files on remote web servers. Implemented with the Apache Web server DAV module.

Other services can be deployed on resource slices, a collection of virtual machines obtained and managed as IaaS using the aggregate of available cloud resource devices.

Communication tools: Two mailing lists give support to Cloudy users and developers[6]. A web site and wiki describe Cloudy[7]. To contribute to the development of Cloudy or report bugs, users can register in the dev site[8].

4.4 Participation framework

License: A Community Cloud Commons License (CCCL) which harmonises the contribution and usage of the cloud resources will play a key role in the take-up process of the community cloud model in a similar way as the influence the network license has had on the network infrastructure. The license must take into account facts like the relationship between users and service providers, among service providers, and also the coexistence with the NCL, which, as already said in the previous section, must be accepted by any participant to join the community cloud. The CCCL has not been established yet. Similar to the NCL process, the steps to write the CCCL licence will go through deliberation with the community. We propose that the license must cover at least the following aspects:

Service level agreement: Mainly to distinguish between best effort services given for free and paid ones. As already discussed, the promotion of economic transactions is crucial for the sustainability and expansion of the ecosystem.

Privacy: In an architecture where sensible data is distributed across the network, privacy protection must start from the license.

Fair use: Rules of conduct and means of control should be specified in order to avoid abuse of the resource in commons.

Transparency and accountability: As already discussed, accountability is essential in any CPR and thus, so is the access to information.

Reference authority: The fact of having a license is tightly related to the existence of an authority which maintains it and makes sure that it is respected. A decision on the convenience and the viability of having such organisation must be made. Existing organisations such as the guifi.net Foundation can be considered to fulfil this role.

[6] Cloudy users: `https://llistes.guifi.net/sympa/info/cloudy-users` and developers: `https://llistes.guifi.net/sympa/info/cloudy-dev`

[7] Documentation for users: `http://cloudy.community/`, and developers: `http://en.wiki.guifi.net/wiki/What_is_Cloudy/`

[8] Contributions to the Cloudy software: `http://dev.cloudy.community`

Collaboration agreements: As with the network infrastructure, the level of commitment of the operators with the commons is expressed through an agreement. The set of collaboration agreements for the cloud shall contribute to enhance confidence among operators offering cloud services. It must be investigated if a graduated commitment system applies to cloud services and/or if it must be service specific.

4.5 Governance tools

The governance involves all actors to drive a community cloud infrastructure through challenges and changes to keep it operational and balanced, key to resilient and adaptive CPRs. The two main tools are the following:

Conflicts resolution system: The already existing system for the resolution of conflicts can be applied as is to community cloud related issues.

Economic compensations system: A clear economic compensations system is needed to clarify the terms of participation, promote investment, and reduce the number of disputes. The already existing compensations system adapted to fit the cloud requirements can be used to balance expenditure. In addition, the impact that the usage of the cloud services may have on the network infrastructure and its effects on the economic compensations system of the network must be investigated to determine if the current calculation system, which is based on the total amount of network traffic at the Points of Presence, must be adjusted.

5 guifi.net community cloud implementation

5.1 The guifi.net community cloud

The most convenient way to for a participant to join and contribute to the community cloud is to install the Cloudy distribution in a small network-attached host (Cloud Access Point). Figure 1 shows its Web user interface after installation at the user's device. Cloudy ensures the provision of a basic set of common services which every participant must be able to join and interact in the community cloud. In addition, it offers an standard way to add new services.

Cloudy[9] can be installed as: *a*) ISO installation image, to be copied to a any bootable device (e.g. USB memory)[10], *b*) Container filesystem, to be used in LXC or OpenVZ[11], *c*) Script, to be run on top of any Debian based distribution[12].

Cloud Resource Devices can be just installed by registering a small network-attached host on the Resource Controller and downloading a bootable firmware image to be run on the new device from a USB memory. After that the RD becomes available as part of a resource pool through its controller.

[9] Distributed in *stable* and *unstable* versions: `http://cloudy.community/download/`
[10] `http://repo.clommunity-project.eu/images/stable/cloudy.iso`
[11] `http://repo.clommunity-project.eu/images/stable/cloudy.container.tar.gz`
[12] `https://github.com/Clommunity/cloudynitzar`

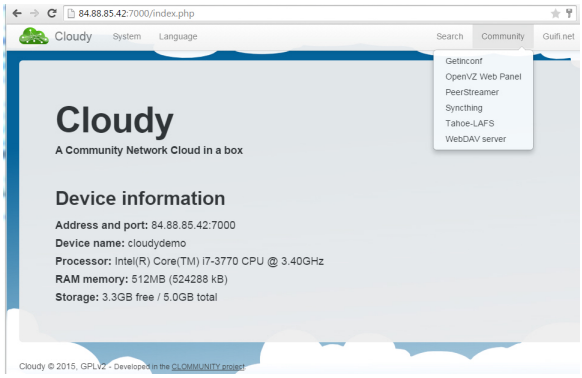

Fig. 1. Cloudy distribution Web user interface.

5.2 Assessment of usage and engagement

The experimental guifi.net community cloud became operational in summer 2015. We measured the technical usage of the community network cloud in terms of instances deployed and services provided. Despite numbers may vary as it grows, a few indicators of its size are shown in Table 1. There are 37 instances in the Serf cloud, 22 contributed by the Clommunity project and 15 contributed other parties like volunteers, schools, companies. The guifi-proxy3 is the most popular guifi.net service and syncthing the most popular of the additional services. In addition, 83 Cloud Resource Devices are currently available for the deployment of arbitrary services. In terms of number of participants, the mailing lists show 47 subscribers to the user's list and 23 subscribers to the developer's list.

	Indicator: Number of ...	**Amount**
Hosts	Clommunity CAP	22
	Third-party Cloudy CAP	15
	Resource Devices	83
Services	Dnsservice	5
	OWP	4
	Peerstreamer	5
	guifi-proxy3	7
	Serf	37
	Snpservice	5
	Syncthing	7
	Tahoe-lafs	3

Table 1. Community Cloud indicators.

6 Conclusion

Citizen community clouds, are motivated by their disruptive potential for changing the future cloud service landscape by extending the current cloud service offerings with local cloud resource and service infrastructures open for access (usage), and open for participation (construction, operation, governance).

The paper argues to organize these citizen community clouds as common pool resources (CPR). To this end, the paper reviews first the mechanism which have led the guifi.net community network to become sustainable at the network infrastructure level. Then specific issues for the applicability of these mechanisms in community cloud-based services are discussed. A framework of components to govern such a community network cloud is presented, where some of these components have been already implemented. The status of the starting community cloud deployment in guifi.net is assessed, which reveals the user interest and acceptance of the provided tools. The deployment of the tools and usage also suggests the technical feasibility of such a cloud system to be built, used and governed by citizens.

The next steps will need to include the development of components to measure and account the contribution to and usage of the cloud CPR, to enable that the economic compensation system, already applied at the network level, can operate also at the cloud level. Initial interest from SMEs to experiment with close-to-market services upon the cloud CPR should help to develop the business models for this ecosystem.

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