Supporting Cloud Deployment in the Guifi Community Network

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***Abstract*—Community networking is an emerging model of a shared communication infrastructure in which communities of citizens build and own open networks. Community networks offer successfully IP-based networking to the user. The number of application and services which are deployed within community networks, however, is surprisingly low, making community network loose an opportunity of having an important additional value for society. Cloud computing infrastructures, common in today's Internet, hardy exist in community networks. We analyze in this paper the characteristics of community networks in order to derive scenarios for community clouds, leading to a set of requirements that clouds in community clouds will need to satisfy. We then explain our approach to bring clouds into the Guifi community network. We have integrated part of our cloud prototype into the Guifi community network management tools, an important step for user acceptance and take up. Our proof-of-concept cloud infrastructure that is currently under deployment in the Guifi community network emphasizes cloud applications and services in order to gain the participation of users. Our long term vision is that the users of community networks will not need to consume cloud applications from the Internet, but find them within the community network.**

***Index Terms*—community networks; cloud computing;**

I. Introduction

The community cloud we present in this paper is the vision of a cloud deployment in community networks: A cloud hosted on community-owned computing and communication resources providing services of local interest. The concept of community clouds has been introduced in its generic form before, e.g. [1], [2], as 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 of both.

Despite the lack of reliable statistics, community networks seem to be rather successful and there are several large community networks in Europe, having from 500 to 20000 nodes, such as FunkFeuer[1], AWMN[2], Guifi.net[3], Freifunk[4] among many others. Most of them are based on Wi-Fi technology (ad-hoc networks or IEEE 802.11a/b/g/n access points in the first hop, long-distance point-to-point Wi-Fi links for the trunk network), but also a growing number of optic fibre links have started to become deployed [3]. Figure 1 shows the wireless links and nodes of the Guifi.net community network in the area of Barcelona.

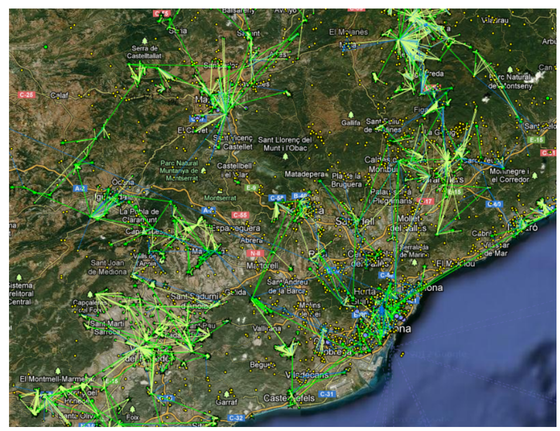

Fig. 1. Guifi.net nodes and links in the area around Barcelona

While community networks are a successful case of resource sharing among a collective, resource sharing in community networks in practice however is done mainly by the sharing of the nodes' bandwidth. This sharing enables that traffic from other nodes is routed over the nodes of different node owners. Since this is done in a reciprocal manner, community networks successfully operate as IP networks. We emphasize that computing and storage resource sharing, which is now common practice in today's Internet through cloud computing, hardly exists in community networks. We argue that in the same way as the bandwith is successfully shared among community network participants, this sharing should be extended to other computing resources through clouds, to offer in a flexible way more applications inside of the community network, which will finally boost the potential of such open, neutral and collecively managed communication infrastructures.

Such a community cloud built in community networks inherits the challenges of community networks, and will need to cope with:

[1]http://www.funkfeuer.at
[2]http://www.awmn.gr
[3]http://guifi.net
[4]http://start.freifunk.net

- Hardware and software diversity: The network nodes and computers are often inexpensive off the shelf equipment with large heterogeneity in the hardware, software, and capacity.
- Decentralized Management: The network infrastructure and the computers are contributed and managed by the users. They belong to the users and are shared to build the network. There is usually no (or a rather weak) central authority that is responsible for resource provisioning.
- Dynamics: The number of network and computing nodes may rapidly change when members join or leave the network, or when nodes overload or fail.

In this paper we present our approach for clouds in community networks, which builds upon key characteristics of community networks and the scenarios we foresee for community clouds. We describe as a particular use case the deployment that we have undertaken in the Guifi community network. Beyond our specific solution, however, we believe that the identified community cloud scenarios and our approach should find applicability in other community ICT infrastructures. We therefore see a big opportunity for the networking and systems community to further develop and contribute such solutions to allow these community infrastructures satisfying a community's demand for Internet access and ICT services.

II. Local and Federated Clouds in Community Networks

In this section we analyze first the conditions of community networks that need to be taken into account when developing the scenarios for community clouds, and then state the two main scenarios we foresee for community clouds. Since our community cloud aims to be used in real community networks, it is a must that our architecture, design and implementation fits into these conditions and scenarios. We focus our explanation on the Guifi.net community network, which with more than 20000 operational nodes can be considered the largest community network worldwide.

A. Community Networks

1) Topology of community networks and hardware aspects: A community network distinguishes between super nodes (SN) and client nodes (CN). Super nodes have at least two wireless links, each to other super nodes. Most super nodes are installed in the community network participant's premises. A few super nodes, however are placed strategically on third party location, e.g. telecommunication installations of municipalities, to improve the community network's backbone. Client nodes only connect to a super node, but do not route any traffic. A topological analysis of the Guifi.net community network [4] indicates that from approximately 17000 analyzed nodes of Guifi.net, 7% are super nodes while the others are client nodes.

Figure 2 shows the outdoor devices of a community network super node. The equipment that is shown are antennas with integrated routers. They are used for building wireless links between super nodes.

Fig. 2. Super node with outdoor hardware for wireless links between community nodes

Figure 3 shows an example of the indoor hardware attached to a super node. The router is a Microtik RB750. A Jetway bare bone device can be seen that is contributed, as we will describe in later sections, as resource to the community cloud. A laptop is used as additional server. A UPS keeps the node running in case of power failures. It can be noticed that a large number of different hardware is used in community networks.

Fig. 3. Indoor hardware of a community network node with router, server and cloud resource

2) Social aspects of community networks: Personal and social relationships play an important role in the community network deployment. The deployment of new nodes need the collaboration among people. If a new node is deployed, the owners of the neighbouring nodes need to connect with it, thus there has to be an interaction among the people.

Guifi.net is organized in zones. A zone can be a village, a small city, a region, or districts of a larger city. We note that while the allocation of IP addresses and layer 3 networking is agreed among all Guifi zones, which is needed to make the IP network work, the detailed technical support is rather given within the community of the zone. Therefore, we identify a zone to have the highest social strength within the community network.

3) Members of community networks: Participants of community networks are consumers and producers of the network. Most of them as producers contribute infrastructure and time to the network. As consumers, they use the available services. However a community network does not work solely based on contribution of infrastructure. Some users must also contribute time and knowledge. Time is needed for instance for maintenance tasks (tasks which might require technical knowledge or not). Technical knowledge is needed because the network is an IP network which needs to be managed and configured. In a large community network there are users with all kind of educational background, but we cannot expect most of them to have engineering background. It can be seen from this analysis that the software that will be used in community clouds must have reduced complexity and easy maintenance.

4) Resource sharing in community networks: Reciprocal resource sharing is in fact part of the membership rules or peering agreements of many community networks. The Wireless Commons License[5] (WCL) of many community networks states that the network participants that extend the network, e.g. contribute new nodes, will extend the network in the same WCL terms and conditions, allowing traffic of other members to transit on their own network segments. We observe that the current concept of resource sharing in community networks is focused on the network's bandwidth sharing. Currently, there seems not to be much awareness about sharing of other computational resources, such as storage or CPU, inside of community networks. The concept of sharing additional computing resources needs to be brought to the community network members.

5) Knowledge sharing in community networks: The knowledge sharing in the community networks can be done with the sharing of documentation and software, using the proper licenses for the content and collaboration.

The Guifi.net web pages are licensed under the Creative Commons license by-nc-sa[6]. It allows users to participate in the contribution of content to the web site, sharing their knowledge and the content to be used by other users.

On the software side, licensing the software under some of the Free Software[7] licenses[8] as the GPL[9] makes the community network open for contributions and allows the future development of the software by others. Free Software licenses allow users to join and continue the work being done. Community networks appreciate, incentivize and use Free Software.

6) Ownership of nodes in community networks: Typically a new member that wants to connect to the community network, contributes with the hardware required to connect to other nodes. A node of a community network therefore belongs to the member who is its sole owner.

[5]http://guifi.net/es/ProcomunXOLN
[6]http://creativecommons.org/licenses/by-nc-sa/3.0/
[7]http://www.gnu.org/home.en.html
[8]http://www.gnu.org/licenses/licenses.en.html
[9]http://www.gnu.org/licenses/gpl-3.0.en.html

Although less typical, a few nodes in Guifi.net have also been successfully crowd-funded if such a node was needed by several people. Such cases happened for example when in an isolated zone a new super node was needed to connect a number of users to another zone.

We can see that both options, individual ownership and crowd-funding of resources, has happened and could be considered as way to contribute infrastructure to community clouds.

7) Services in community networks: Services and applications offered in community networks usually run on the machines that the member connect to its node and these machines are used exclusively by that member. The usage of community network services within the community network, beyond that of access to the Internet, is not very extended.

B. Community Cloud Scenarios

Given the socio-technical characteristics of community networks described above, we start sketching our vision of community clouds. In Figure 4, some node types of a community network are depicted. The picture shows some typical community nodes with a router and some server or clients attached to it. Some clients nodes (CNs) are shown that are connected to the access point (AP) of a super node (SN). In addition, however, these community nodes have cloud resources attached to them. We derive the community cloud scenarios for these resources in the following.

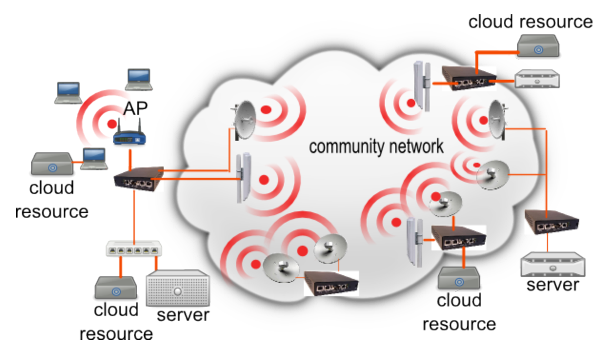

Fig. 4. Nodes in a Community Network

1) Local Community Cloud: The scenario of the local community cloud is derived from the topology of the community network and the observed characteristic of the strength of social network within zones.

In the local community cloud, a super node is responsible for the management of a set of attached nodes that as hosts contribute cloud resources. From the perspective of the attached nodes, this super node acts as a centralized unit to manage the cloud services. The super node connects physically with other super nodes through wireless links and logically in an overlay network to other local cloud managing nodes.

Given such local community clouds and uptaking results from the analysis of the community network topology [4], a hierarchical federated architecture [5] for the integration of these local community clouds is suggested.

2) Federated Community Clouds: Given a set of local community clouds, multiple super nodes in a community network will connect and form federated clouds [6]. Such federated clouds are transient and can grow or shrink and merge or split and form larger cloud systems. When there is a sufficient number of sites in a federated cloud, some of the more resourceful SNs can take additional responsibility of the management and coordination for neighbouring SNs.

III. Requirements

The conditions of the community network explained in the previous section determine the constrains to which a community cloud has to fit to. While these conditions leave room for different visions within the given limits, we concretize our system as follows, and derive its requirements. A community cloud is a combination of a number of cloud systems running independently by the different community members. Moreover, the amount and quality of resources available at each individual cloud can vary a lot. In community clouds, resource distribution is very different from the existing commercial public clouds which are deployed on data centres using clusters of mostly homogeneous computers. It is also different from private and hybrid clouds where resources, though not as abundant as data centres, are still consolidated into larger entities. In contrast, in community clouds, there may be tens or even hundreds of sites, but each site may only consist a few tens of machines.

The following requirements provide the foundation for the architecture of the community cloud system, that need to be satisfied for it to be deployed and adopted successfully by the community.

A. Autonomy

Individual cloud systems are set up and managed independently by different owners. This means that each cloud owner can take decisions about his or her cloud setup without negotiating with other partners beforehand.

B. Security

With multiple independent cloud operators, security becomes even more important in a community cloud. There are many security challenges[7] that need to be addressed for ensuring users' trust in the system.

C. Self-Management

The community cloud should self-manage itself and continue providing services without disruption when nodes leave and join the system. One important aspect is the coordination between different cloud owners that are part of the federated community cloud.

D. Utility

For a wide adoption of the community cloud, it should provide applications as a service that are valuable for the community, and this would drive the growth of the community cloud.

E. Ease of Use

Most of the users of the community cloud will not be proficient in cloud technologies, so setting up nodes for deployment and managing cloud software should be simple and straightforward.

F. Incentives for Contribution

For community clouds to be sustainable, incentive mechanisms are needed to encourage users to actively contribute towards the system.

G. Standard API

The cloud system should make it straightforward for the application programmers to design their applications in a transparent manner for the underlying heterogeneous cloud infrastructure. An API should obviates the need to customize the applications specific to each cloud architecture.

IV. Integrated network and service architecture

In order to guide the development of the cloud system, an overall architecture is needed that integrates the different layers of the cloud system. Figure 5 shows a layered architectural view that we propose which integrates the users, software, hardware and the network. From a top-down perspective, from the end user to the hardware components and community network access, the following layers are given:

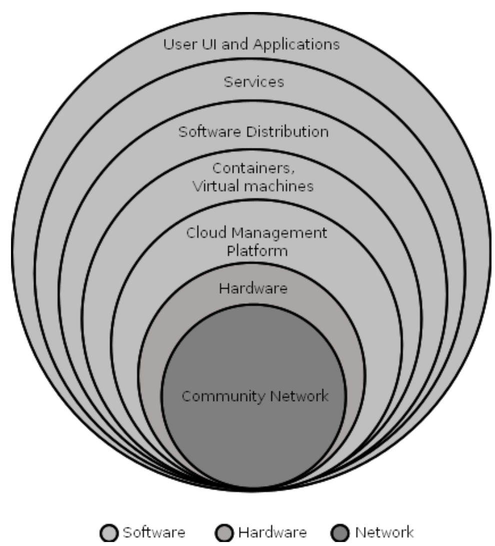

Fig. 5. Network and service architecture

- User UI and applications. These elements provide the end-users with applications and user interfaces to interact in a transparent way with the underlying community services.
- Services. These services are provided by the community software distribution. Service discovery and distributed storage are examples of these services. As examples, applications that we currently use are: 1) Avahi: Avahi is a free software Zeroconf implementation. The services in the community cloud are published and located using

this tool. Any host can get a list of services running in the cloud without knowing previously nothing more than a command or browser tool. 2) Tahoe-lafs: The Tahoe application is a distributed file system that can be used for storage in clouds.

- Software Distribution. It is the software distribution that runs over the underlying layers, i.e. it runs in the containers or virtual machines. This provides a way to pack and distribute the cloud services in a single platform. This distribution is what we call the *Guifi-Community-Distro*. It is the core of our cloud system, because it unifies the different tools used in the cloud system in a Debian-based Linux distribution. We build the distribution using different sources of packages that work together.
- Containers and Virtual Machines. The elements of this layer can be containers, virtual machines or similar elements. They are created by the cloud management platform. The virtual machines are the environment where the community software distribution is installed.
- Cloud Management Platform. This layer contains the software needed to manage the cloud platform which communicates the underlaying hardware layer with the software distribution layer using standard Linux tools and manages the containers and virtual machines layer. Examples of popular open source cloud management platforms are Open Nebula[10] and OpenStack[11]. In our case, as we will describe in the following sections in more detail, we use the Community-Lab testbed software[12] built by the CONFINE project[8], [9], which provides nodes inside of the Guifi community network.
- Hardware. This layer represents the cloud hardware layer. This hardware is integrated into the community network. It is connected to the community network. Rart of the cloud management software is installed on it.
- Community Network. This is the community network. In our case, it is the Guifi.net community network.

V. Deployment of the Community Cloud in Guifi.net

In this section we describe how the community cloud is brought into the Guifi community network with the technical support of the community network management software and the social support of Guifi community network members. Our cloud deployment is in the starting phase and on-going, and done with the help of the CONFINE project [9] which provides the Community-Lab testbed for the deployment of the initial cloud nodes, and the CLOMMUNITY project [10], which allowed us to engineer the community cloud system.

A. Steps to install a Community Cloud node

The typical process that a user follows to add a new devices to Guifi.net is to register it in the web interface hosted at the Guifi.net server. In order to install a community cloud node, the Guifi user applies the same mechanism he/she already knows. The steps are illustrated in the following figures. Figure 6 shows general information about a real existing node in Guifi.net. Figure 7 shows in a map where this node is physically located. Finally, as can be seen in Figure 8, the web interface allows the user to add devices to the node. It can be seen that the user can select the *Confine/Clommunity* device, which refers to a cloud resource.

[10]http://opennebula.org
[11]http://www.openstack.org
[12]http://community-lab.org

node	1655 VicBarriOsona	**VicBarriOsona**
zone	Vic-6 (S) Santa Anna, Plaça Osona, Sanferm	Antic Camí a Taradell, 26
position (lat/lon)	Lat:41.915561 Lon:2.260303	15 meters above the ground
available for mesh & status	Yes	Working
graphs provided from	Take from parents	

contact information

email contact (available if you are logged in) · created by: MiquelM at 30/11/1999 - 1:00am · managed by: webmestre · updated by: MiquelM at Mon, 22/10/2012 - 18:24

Fig. 6. VicBarriOsona node info page at guifi.net web: step 1 of 3, node information (source: http://guifi.net/en/node/1655)

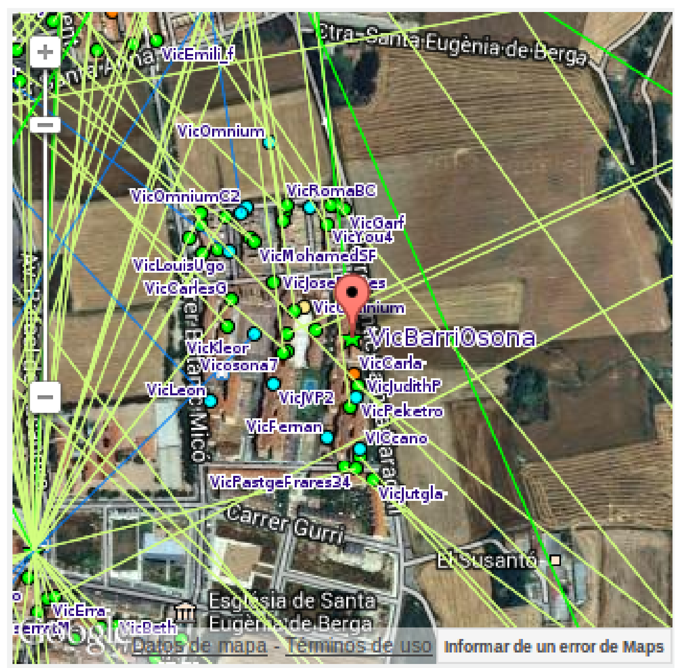

Fig. 7. VicBarriOsona node info page at guifi.net web: step 2 of 3, node map (source: http://guifi.net/en/node/1655)

In the same way as for any other devices in Guifi.net, the details of the deployed Confine/Clommunity devices can be seen, such as illustrated in Figure 9. The detailed view for the Confine/Clommunity device provides information such as

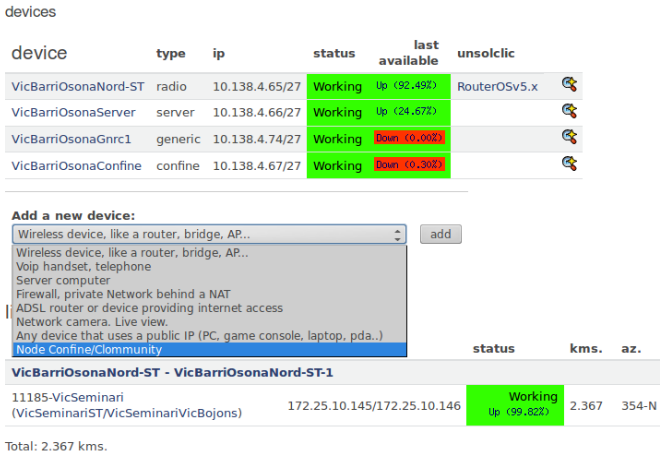

Fig. 8. VicBarriOsona node info page at guifi.net web: step 3 of 3, add cloud resource (source: http://guifi.net/en/node/1655)

graphs, statistics, uptime, and IPs for the device.

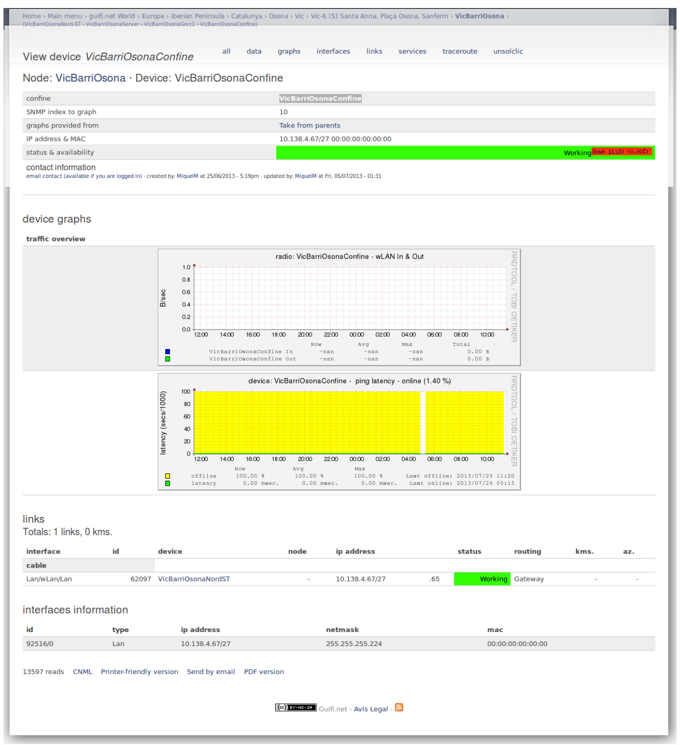

Fig. 9. VicBarriOsonaConfine Confine/Clommunity device detailed view at guifi.net web. Source: http://guifi.net/ca/guifi/device/54912

B. Community Box as cloud hosts

The hardware that we currently deploy as hosts of the community cloud are bare bones devices of type Jetway JBC362F36 (Figure 10), which we call *community box*. These devices were chosen due to their low power consumption in order to be operational at the user premises at low cost in 24/7 mode and due to being fanless and without moving parts. They are equiped with Intel Atom N2600 CPU, have 4GB RAM and a 120GB SSD.

Fig. 10. Community Box as host in the community cloud

C. Cloud management platform

The community boxes used as cloud host need to be managed, in terms of their virtual machines, for monitoring, update etc. Currently, we use the management software of the Community-Lab testbed[13], with which the community boxes are integrated into its management services. Different to other open source cloud management platforms, the management software of the Community-Lab allows us manage cloud resources with OpenWRT as host operating system, which is the case of the community boxes. The Community-Lab management software allows the user the creation of slices, i.e. a set of virtual machines on different community boxes. Finally, as can be seen in Figure 11, the user can select the Guifi-Community-Distro (see next section) to be loaded as operating system image into the virtual machines of the slice. This is a very important feature since, as we described in previous sections, the Guifi-Community-Distro contains main cloud support services such as Avahi, and by distributing this image to the cloud hosts, we assure that these services run on every cloud device.

D. Guifi-Community-Distro and Cloud services

The cloud infrastructure service of the Community-Lab management software (see previous section) provides the user with a set of virtual machines. The *Guifi-Community-Distro* is the operating system image which we have prepared to be placed in each virtual machines. The Guifi-Community-Distro is a Debian-based distribution which has been equiped with a set of basice platform services and applications. Some of these services are common with other Guifi devices, such as the graph server and the proxy service. Other services, such as Avahi[14] and Tahoe-lafs[15], have been explicitly added to the Guifi-Community-Distro as cloud platform and application service, respectively.

Figure 12 indicates some of the already given and planned services. The Avahi service is particularly important for the cloud system since it allows the location of services, and with

[13]http://community-lab.net
[14]http://avahi.org/
[15]https://tahoe-lafs.org/ warner/pycon-tahoe.html

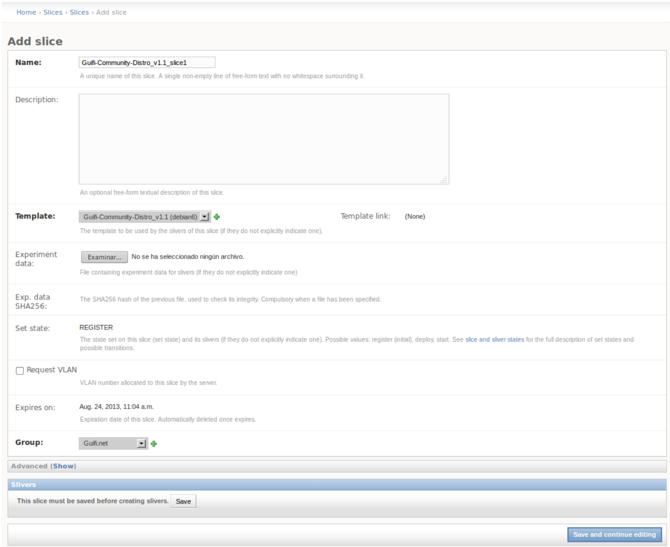

Fig. 11. Create a slice the image of the Guifi-Community-Distro v1.1 though the Community-Lab testbed controller (source: http//controller.confine-project.eu)

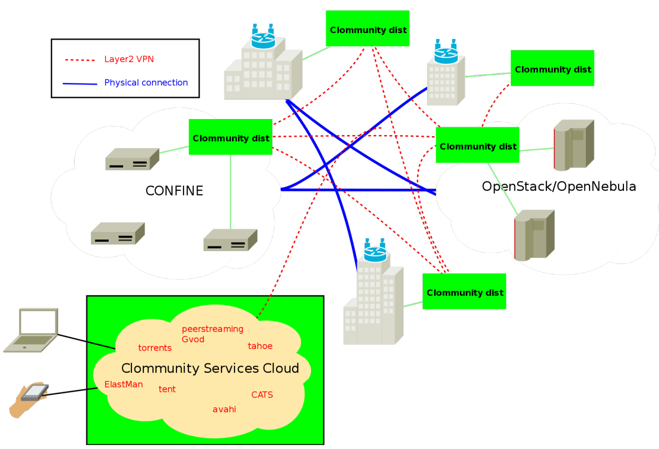

Fig. 12. Global community cloud deployment scenario

additional software even outside of the LAN (though further research and additional tests are needed). This way services can be seen from any node of the cloud, and with the use of the browse capabilities of Avahi, the cloud user experiences a vision of an uniform integration of services within the cloud. Some tests with Avahi in the Guifi-Community-Distro have shown promising results: We have created a slice among a few community boxes and installed the Guifi-Community-Distro in the virtual machines belonging to the slice. We deployed a few cloud hosts with the use of the Community-Lab testbed in Guifi.net and installed the Guifi-Community-Distro. The nodes could see each other and the Tahoe-lafs services published with Avahi and could be accessed between the nodes of the test cloud.

VI. Key Elements to Bring Cloud into Community Networks

While the deployment of the community cloud we described is an on-going work, we discuss in this section some aspects which we consider highly relevant for having achieved that already now some cloud nodes are in the Guifi community network.

1) Focus on cloud applications services: We have decided to focus in the community cloud on the provision of platform and application services, rather than on infrastructure service. As a consequence, regarding cloud infrastructure services, we currently rely on Community-Lab (or could use other open source cloud management platform such as OpenNebula and OpenStack) to deploy virtual machine instances. The decision for that was taken since we expect that the community network user will only participate in the cloud, at the beginning as user and later potentially as resource provider, if interesting services are running.

2) Integration of the cloud in the community network management software: In order to reach the community network users, cloud hosts can be selected by the user in the Guifi web interface as devices to be attached to community network super nodes (as in Figure 8), similar to other devices such as routers, bridges etc. The web support is an important demonstration to the end user that cloud devices are supported in the community network. A pending step in this direction is that the cloud image for the virtual machines, i.e. the Guifi-Community-Distro, is also available from the Guifi web page. Currently, we provide it through the web interface of the Community-Lab mangement software (as in Figure 11).

3) Access to community network nodes for initial cloud deployment: Our approach is to deploy an operational prototype of the community cloud, which is needed such that the end user can really test and use cloud services. If our cloud would have been provided as a laboratory experiment, it would hardly become ever integrated in the community network. This access to the Guifi community network was facilitated through the Community-Lab testbed, which offers nodes for experiments in community network. The initial cloud nodes which we have deployed allow to offer within the community network these services open to end users, and raise the end users' interest.

4) Sustainability of the community cloud: Community networks are maintained by volunteers. While the building and maintenance of the network layer is already complex, the administration of a cloud might require even more specific knowledge. In order make the cloud administraution sustainable, open source software that is in production stage and which has a wide user community must be applied. In order to achieve an ecosystem of cloud providers and consumers, incentives for the users such as quality of experience should be integrated in the cloud system. An incentive mechanism should reward the contributions of the end user to the cloud, leading to a system that associates the allowed resource consumption with the users' contributions.

VII. Related work

The vision of community cloud computing has been described in [2]. The authors outline the conditions of a community and how a cloud system could be designed for such conditions. While the theoretical contribution of this paper is very relevant for our work, the authors did not really develop any real cloud system beyond the proposed architecture.

On the level of complete systems for community cloud computing, there are a few research prototypes, but none for community networks such as targeted by us. Skadsem et al. [11] provide applications for communities by using local cloud services. Their context is similar to ours though they assume that the social mechanisms like trust in a small community do not require additional mechanisms such as incentives. The Cloud@Home[16][12] project has similar goals to harvest in resources from the community for meeting peaks in resource demands. The system is well described in terms of design and motivation, but a deployed systems seems not yet to be available. The Clouds@home[17][13] project focuses on providing guaranteed performance and ensuring quality of service (QoS) even when using volatile volunteered resources connected by Internet. The authors focus on voluntary computing systems, but do not consider the particular context of community networks. The P2PCS[18][14] project has built an initial prototype implementation of a decentralized Peer-to-Peer cloud system. It uses Java JRMI technology and builds an IaaS system that provides very basic support for creating and managing VMs as a slice. It manages slice information in a decentralized manner using gossip protocols. The system is not completely implemented and integrated.

From the review of the related work it can be seen that the socio-technical challenges that we find in community networks are not addressed comprehensively by the related work, and systems are usually not deployed. In the cloud system we propose we put emphasis on the feasibility of deployment and aim that it is really used. The cloud system proposed in our work should become part of a production system to be used in real community networks.

VIII. Conclusion

Community clouds are motivated by the additional value they would bring to community networks. A vast amount of applications could be deployed upon community clouds, boosting the usage and spread of the community network model as ICT infrastructure for society.

This paper analyzes key socio-technical characteristics of community networks to derive two community cloud scenarios, the local community cloud and the federated community cloud. Subsequently, requirements are stated that a community cloud should satisfy. An integrated network and service architecture is scetched to help in building the overall system. It is a strategic decision to use and integrate existing platforms and cloud software systems to be able to achieve a fast deployment of a cloud system integrated in the Guifi community network with mature software. The goal is to achieve cloud applications which the community network end user can use and which will motivate his/her participation, a key for the sustainablity of the community cloud at the long term.

While our deployment of cloud hosts in Guifi.net is ongoing, we hope to achieve soon the availabily of services to end users. The feedback from end user participation and experience is needed to further shape the development of the community cloud components such that this community cloud within the community network will ultimately be used as alternative to the commercial clouds in the open Internet.

[16]http://cloudathome.unime.it

[17]http://clouds.gforge.inria.fr

[18]https://code.google.com/p/cloudsystem

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