Experiences in Building Micro-Cloud Provider Federation in the Guifi Community Network

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***Abstract*—Cloud federation is foreseen to happen among large cloud providers. The resulting interoperability of cloud services among these providers will then increase even more the elasticity of cloud services. The cloud provisioned that is targeted by this scenario is mainly one which combines the cloud services offered by large enterprises. Cloud computing, however, has started moving to the edge. We now increasingly see the tendency to fullfil cloud computing requirements by multiple levels and different kind of infrastructures, where the Fog Computing paradigm has started playing its role. For this scenario of edge computing, we show in this paper the case of the federation of multiple independent micro-cloud providers within a community network, where providers pool their resources and services into a community cloud. Federation happens here primarily at the service level and the domain of trust is the community of practice. While we can today already report this case in the context of community networks, IPv6 deployment in the Internet will principally allow micro-cloud providers to appear everywhere, needing cloud federation mechanisms. We describe for a real case how this micro-cloud provider federation has been built and argue why micro-cloud provider should be considered for the integration in cloud federations.**

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

I. Introduction

We consider service provision in community networks (CNs). CNs are IP-based networks which are built and operated by local communities of citizens. Hundreds of CNs operate across the globe, in rural and urban, rich and poor areas. The origin of CNs is mostly the need for Internet access in under-served areas. It has been recently recognised, however, that there is the opportunity to offerfrom *inside* the network several of the services currently consumed from the Internet [1]. This would not only reduce the traffic at the Internet gateways, but would bring the opportunity for the users to recover the control over their data and contents.

Community clouds have been defined as cloud computing models where the cloud infrastructure is built and provisioned for use by a specific community of consumers with shared concerns, goals and interests, and is owned and managed by the community or by a third party or a combination of both [2]. Commercial community cloud solutions are a reality nowadays in several application areas such as in the financial, governmental and health sector, fulfilling their community-specific requirements [3] [4]. Within CN, the possibilities of community clouds has just become unveiled [5]. The micro-clouds federation we present in this paper are part of a real deployment which materializes the vision of a community cloud for CNs, hosted on community-owned computing and communication resources providing services of local interest.

The deployed community cloud in the CN, which we report in this paper, matches in several components the vision of the IEEE p2302 Intercloud WG [6][7], but differs in scale, distribution and decentralization. The community network cloud (CNC) consists of many small cloud providers which for interoperability rely on a set of common services. In this sense, we can consider the CNC as a specific case at the local level for the federation of cloud providers. Given the characteristics of the system which we report in this paper, we argue that cloud federation should not only be horizontal among large providers, but also vertical in order to integrate the cloud service providers from the edge.

The contributions of this paper are the followings:

1) Identification of federation structures in an edge cloud computing scenario.
2) Micro-cloud provider federation in a community network cloud.
3) Deployment status and outlook.

The structure of this paper is as follows: In section 2 we review federation structures that appear in communities at the edge. Section 3 describes how micro-cloud providers have been federated in the CN. In section 4 we discuss the status of the community cloud system and sketch the needs for vertical Intercloud interoperability, in addition to horizontal interoperability. We conclude the paper in section 5.

II. Federation Concepts in Community Networks

In this section we review federation concepts applied in CNs, and unveil similarities with the foreseen federation of cloud providers in the Internet. Our study focuses on

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Guifi.net[1], which with more than 30.000 nodes can be considered the largest CN worldwide.

Network level: The community network grows organically by each new networking node that is contributed by a participant. A community network distinguishes between super nodes, also called backbone nodes, and client nodes. Super nodes have at least two (wireless) links to connect to other super nodes. Therefore, traffic is routed over them. The interconnection of super nodes in the network nodes is essential in order to be able to achieve a networking service in terms of an IP network, which allows users to reach Internet.

There is a centralized management for the coordination and management regarding IP address distribution in Guifi.net. A super nodes in a community network is typically assigned with an IP address range, e.g. a /27 range, whose addresses are public within the community network[2].

Each super node from a topological point of view is considered as autonomous system, with BGP routing used in the backbone network formed by the super nodes.

Federation in terms of interconnection of network segments is achieved by the BGP routing protocol. The allocation of an IP network segment to the different super nodes is managed centrally from the community network administration.

Peering between super nodes is regulated by the Network Commons License (NCL)[3], which each participant that contributes a super node has to subscribe. According to this license each contributor keeps the ownership of the hardware he/she has contributed, but, as long as it participates in the CN he/she must any inbound transit unaltered.

Ownership of community network infrastructure: Similarly to how the network infrastructure is put in place, participants contribute specific resources to build the CNC, and in the same manner the contributor keeps the ownership of the hardware contributed. However, until a specific license for the services and contents is not available (i.e. proposed and accepted by the community), these services and contents are made available to the discretion of the provider, as the NCL stablishes.

In the federation of clouds, for instance as proposed by the IEEE p2302 Intercloud WG [6][7], it is foreseen that cloud service providers, which are independent of each other in terms of their ownership, will share resources among each other according to (peering) agreements.

Service level: At the level of cloud-based services, micro-cloud providers attach devices to super nodes. The super node assigns a public IP address[4], which allows to have a routable device and offer services to the community. Such a micro-cloud provider can be a community network user which disposes of the super node's network segment and offers a free service, or it could also be an SME which runs a commercial service. These micro-cloud providers can principally offer any type of service (further details are discussed in section III).

[1]http://guifi.net/

[2]We refer to routable IP addresses within the community network which are not behind a NAT.

[3]http://guifi.net/en/FONNC

[4]The address is public within the community network.

Since super node owners are independent of each other, the hardware used to run services on is heterogeneous, i.e. different types of cloud resources can be attached by a micro-cloud provider to a super node.

We can see in Figure 1 how such micro-cloud providers fit into the community network. Cloud resources of different kind (heterogenous hardware) and from independent owners are attached to some super nodes. Services may be of different kind.

Management services though are needed to achieve the federation of these micro-cloud providers. Such federation management services will help the users to use services from different micro-cloud providers. In fact, geographic location and QoS requirements will qualify specific service providers for each user.

Thus, the independent cloud providers in Internet brought together into a federated cloud offer are reflected in the community network in terms of the large number of microclouds.

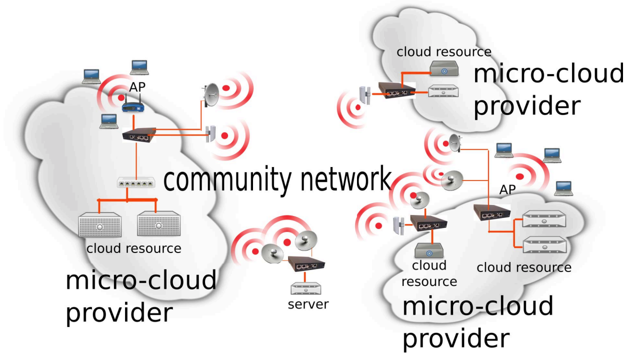

Fig. 1. Micro-cloud providers in a community network.

III. Deployed micro-clouds in Guifi.net

We describe in this section the cloud that has been deployed in the Guifi community network. It is a real system and we explain how this deployment materializes the concept of federation presented in section II.

A. Community Network

Guifi.net is our target community network. With thousand of nodes, Guifi is a very large network, where we can observe the case of micro-cloud providers emerging. Also within Guifi, a sustainable economic ecosystem has been developed since a few years, with several SMEs operating commercially within the network, mainly dedicated to sell improved Internet provision to their customers (which are members of the community network).

Figure 2 shows a map of the links and nodes of the Guifi.net in the area around Barcelona. Lines in the map are links, points that interconnect with other points are super nodes. The figure illustrates the case of micro-cloud service providers, which are geographically distributed in the community network. Through these micro-cloud providers, cloud-based services are provided within the network.

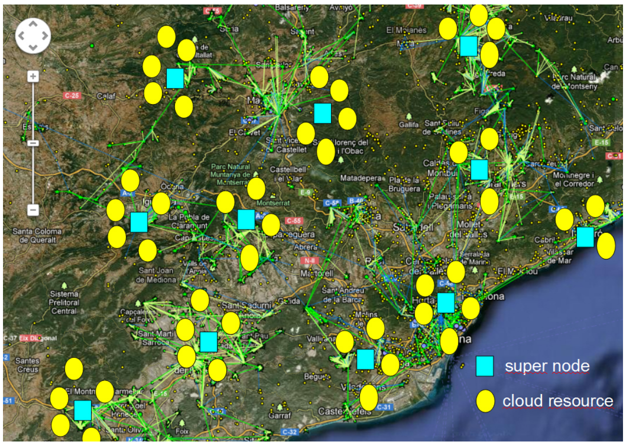

Fig. 2. Guifi.net nodes and links in the area around Barcelona, with illustration of geographically spread micro-cloud providers.

B. Hardware

The hardware to host micro-cloud provider services that is currently deployed at different locations in Guifi.net is heterogeneous (Figure 3). A few nodes are high-end rack-based servers (e.g. PowerEdge R420 rack server), some cloud nodes are desktops (e.g. Dell OptiPlex 7010). These nodes support virtualization by hardware. In addition, however, some deployed cloud nodes represents the case of low-end cloud resources such as home gateways, that end users may provide to the cloud. For such kind of nodes small Jetway device (no support for KVM, only containers) have been used, and more recently Atom-based devices from Minix.

Fig. 3. Hardware used for micro-cloud service provision.

C. Cloudy Software Distribution

1) Cloudy: We have developed a community cloud GNU/Linux distribution codenamed *Cloudy*. It is deployed on the micro-cloud nodes to bring together the individual services of each node into a service offer that is published to the users.

Cloudy[5] is the core of the micro-cloud provider federation, because its support services unify the service offers of the different providers. Cloudy is Debian-based and installs like a standard Debian distribution. It is given in two flavors: as a standalone version to install on real hardware or virtual machines, and as LXC container.

2) Approach: Each community network user that wants to become a micro-cloud provider through the contribution of infrastructure and/or services is encouraged to install the Cloudy distribution. Therefore, Cloudy aims to be deployed on each micro-cloud in the community network, as illustrated in Figure 4.

Each Cloudy instance has a Web-based GUI. It provides to the cloud node administrator and user an easy and comfortable way to install and configure cloud-based applications and community network services.

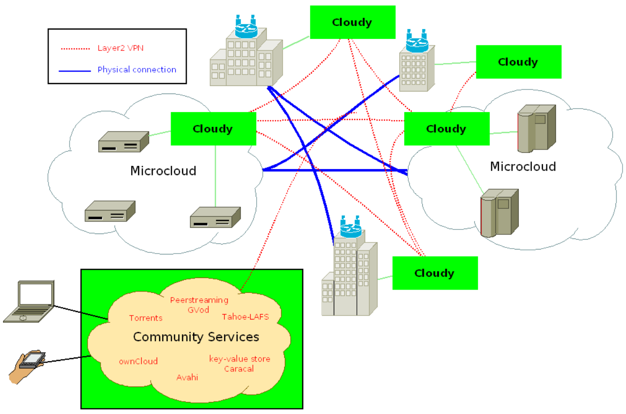

Fig. 4. Cloudy distribution when deployed on hosts of micro-cloud providers.

3) Pre-installed community services: The Cloudy distribution is provided with a set of ready-to-activate services, which community network users are expected to find useful and attractive, grouped into Search, Community, and Guifi.net (Figure 5).

The search service allows the users to find all the Cloudy instances which are deployed in the community network, and discover services deployed in these Cloudy instances. The search service is implemented through Serf [6], which disseminates information among the nodes through a gossip protocol.

The community service menu in the Cloudy GUI shows the applications which come already pre-installed in the Cloudy distribution (it is left to the user to active them or not), see Figure 6. Tahoe-LAFS[7] is included which allows building a secure storage service. For P2P-based live video streaming, Peerstreamer[8] is offered. The Syncthing[9] service allows micro-cloud providers to offer a service similar to Dropbox.

[5]http://repo.clommunity-project.eu/
[6]https://serfdom.io/
[7]https://www.tahoe-lafs.org/trac/tahoe-lafs
[8]http://peerstreamer.org/
[9]https://syncthing.net/

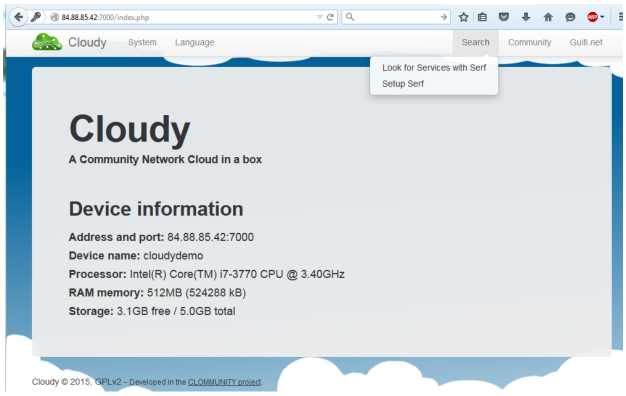

Fig. 5. Search service in Cloudy based on Serf.

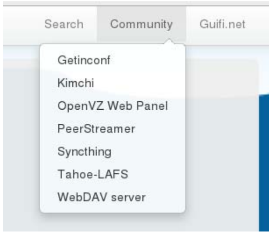

Fig. 6. Application services offered by Cloudy instances.

4) Micro-provider added services: Micro-cloud providers can add their own services, since Cloudy is an open platform. The micro-cloud provider can make these services public or keep them private.

Additional services can be provided installed in several ways: As in any Linux based distribution, a general option to install services is for the owner of a Cloudy node to access as super user and install any additional service in his/her Cloudy distribution. Another option is to follow a number of steps[10] to integrate the service into Cloudy in a way that the search service based on Serf will announce the new available services to the other Cloudy instances. This feature takes advantage of Serf running continuously at each Cloudy instance in the background, where it regularly gossips the services available at each moment. This way, new services are discovered by other users/providers and in the same way, when a service providers stops providing them, they disappear from the list of available services. Services can also be provided through containers in low end devices [8] or through virtual machines in the higher end cloud nodes.

5) Network management services: The Guifi.net services within Cloudy allow to enable a set of community network management services (Figure 7). There are currently 4 services. They include a proxy service based on Squid, usually used to enable Internet access from within the community network, a SNMP service for network monitoring, a DNS service for name resolution within the community network, and a service to integrate the micro-cloud provider's resource into the community network infrastructure database.

[10]e.g.http://wiki.clommunity-project.eu/howto:installpastecat

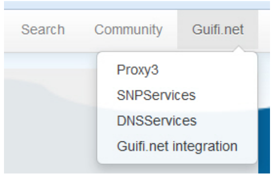

Fig. 7. Cloud node integration in community network infrastructure registry.

6) Identity management for cloud node registration: Each member of Guifi.net registers in Guifi with a user name and password. Micro-cloud service providers must be members of Guifi in order of being able to register their device. Similar to the registration of networking nodes, micro-cloud providers register their Cloudy node. It can be done through Cloudy' Web GUI as shown in Figure 8. During registration, the credentials of the user will be authenticated via LDAP with the Guifi.net member data base.

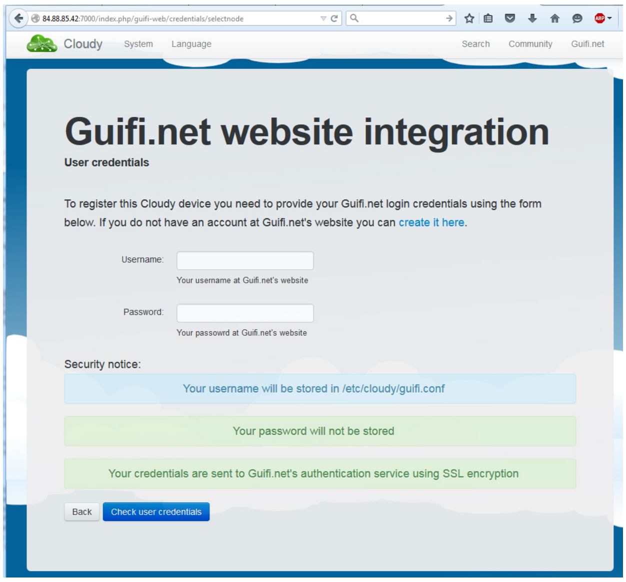

Fig. 8. Registration of micro-cloud provider node in Guifi.net data base.

After registration of the cloud resource, it appears in the Guifi Web site. Figure 9 shows the result of a successful registration of a cloud node attached to a super node.

IV. Discussion

After presenting in the previous section the technical solutions applied for micro-service provision in this community network cloud,we review the current take-up in terms of nodes and services provided, and then elaborate further on the needs and road map for cloud federation.

devices

device	type	ip	status
BCNCanBruixa20snRd4	radio	10.1.9.65/27	Testing
BCN-GS-CanBruixa20-NSM5	radio	10.1.9.66/27	Working
BCN-GS-CanBruixa20-RKM5	radio	10.1.9.67/27	Working
BCNCanBruixa20snSwtch1	switch	/	
BCNCanBruixa-UPC-H	radio	172.25.63.73/29	Working
BCNCanBruixa20snCldy1	cloudy	10.1.9.68/27	Working

Fig. 9. A Cloudy node (last line) successfully registered at a super node [source: https://guifi.net/en/node/54052].

A. Assessment of usage and engagement

We measure the current status of the CNC by the number of instances deployed and services provided. The values are obtained through a publicly available Cloudy instance[11]. Figure 10 shows the evolution of the number of cloudy instances and services along the forth week of September 2015 from the prospective of this public instance. Obviously, the number of cloudy instances will be always the highest followed the number of Serf instances[12]. More interesting is to observe the distribution of the rest of services. Two groups can be clearly identified. The first, with an average around one third of the cloudy instances seen, and the second with only two or three instances in average. The first group is composed by all the traditional guifi.net services (DNS, Proxy, and Graph server) and, interestingly, a distributed mass storage service (Syncthing). In the second group (PeerStreamer and OWP) includes the services less attractive for the community[13].

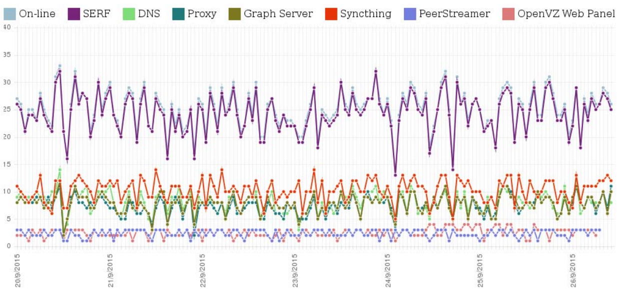

Fig. 10. Cloudy instances and services announced seen by the publicly available Cloudy instance.

Regarding the usability of the services in the CNC, we conducted some experiments on the performance of applications deployed in our cloud. The results are detailed in [9] and [10] and showed satisfactory performance, suggesting suitable quality of experience for end users.

[11] http://demo.cloudy.community User: *guest*, Password: *guest*

[12] Serf is activated by default, thus, in steady state these two numbers should match, unless Serf hasn't been manually deactivated. The rest of the services must be manually activated, thus, we should not expect all services to be running in all instances.

[13] Both were introduced during the development of Cloudy.

B. Architectural comparison between Intercloud standardization elements and micro-cloud provider federation

As previously introduced, there is an on-going standardization effort for cloud federation conducted by the IEEE p2302 Intercloud WG [6][7]. We relate the elements we have observed in the Guifi.net community cloud with those elements foreseen for standardization.

1) Intercloud communication: The Intercloud gateway [6], instantiated at each cloud provider site, aims to allow the different cloud implementations of these providers to interoperate with each other.

The federation of our micro-cloud providers is currently end user oriented, and not machine-to-machine. Serf instances on each node communicate among the nodes information about the services offered by each instance. This information provided to the Cloudy Web GUI, aimed to be seen by the end user. Currently, Cloudy does not provide an API which could be used for additional machine-to-machine communication.

If an Intercloud gateway implementation is available, it should be considered for integration in the more powerful nodes of micro-cloud providers.

2) Service brokers: The Intercloud exchanges are foreseen in [6] as the component to dynamically clear service requests and offers. In our currently developed micro-cloud providers, the service usage conditions and guarantees are not defined. The current search service is restricted to discovery and announcement, leaving service usage agreements to bilateral negotiation between user and provider.

Service brokers, however, will be an important element if in the future the service offers available in the community network cloud goes beyond the basic community services of Cloudy. Once either individuals or enterprises offer free or commercial services to the community, a market place will be needed.

3) Service registry: The function of the Intercloud root [6] includes the (legal) registration of cloud providers. As shown in section III, micro-cloud provider nodes in the community network are registered in the community network's infrastructure database. Service offers, however, are not part of this static registration, since these service offers change dynamically. For this reason, the search service is responsible to provide to the user an up-to-date view on the actual available services.

4) Functional elements: The Intercloud standarization draft describes elements to provide the functions of presence, messaging, resource ontologies, trust and name spaces. The scope addressed by the Intercloud scenario needs a deep design effort to fulfill the requirements of these functions.

In the case of the micro-cloud providers, the scalability towards many tiny instances and self-management is a dominating requirement. Therefore, Serf and no more centralized alternatives such as XMPP was chosen as messaging platform between cloud nodes. A resource ontology, expected to be established within the Intercloud standarization effort, should be considered to replace the current service descriptions transmitted over Serf.

C. The Intercloud federation as an essential part of SME commercial community Micro-clouds

With several micro-cloud nodes deployed by individuals, SMEs have started to explore the opportunity of commercial services to operate upon the basic community services in the CNC. As an example, we mention the study of a commercial backup service extending Cloudy's Syncthing service to run in personalized Linux containers to ensure privacy.

The storage capacity already available in the community cloud nodes contributed by individual users could be used by the SME as starting point, which would reduce its CAPEX cost for the initial hardware investment, and facilitate initial trials.

Interfacing with services provided through a cloud federation given by the Intercloud, however, would improve the SME's capacity to satisfy fluctuations of demands. If we anticipate the trend of the service provision landscape going towards the edge, e.g. to satisfy through SMEs the requirements for the provision of more and more local services, the features of interoperability between cloud providers will become even more important. Successful cloud provision at the edge will need to leverage interoperation capability with several cloud providers.

D. Open issues for micro-cloud providers in communities

Micro-clouds within the community network cloud are expected to reflect the social and geographic structure of the community. From a geographic point of view, community members may obtain a better user experience with services provided by nodes only a few hops away from them.

Regarding the social dimension, levels of trust among members may determine the nodes which form a micro-cloud. It has been shown in previous works [11] that social graph analysis may help to determine the trust among community members.

If suitable metrics are found, Cloudy nodes may be grouped into micro-clouds in an automated way. User preferences may be taken into account to find the best match. As a result, the cloud usability and the user experience would increase.

V. Conclusion

This paper presented elements of the micro-cloud provider federation in the Guifi.net community cloud for providing services to its users. This cloud can be seen as a community cloud, where micro-cloud providers and their federation fit to the specific needs and conditions of this user community.

The presented micro-clouds were compared with the Intercloud architecture, and some similarities were identified in the cloud federation components, as well as the applicability of Intercloud concepts.

This paper suggests the importance of vertical cloud federation, i.e. the integration and interoperation with edge cloud service providers, in addition to establishing horizontal Interclouds. Given the vertical federation, SMEs offering local cloud-based services to the users will be able to create more easily value added services, since the generic cloud resources they need to operate will be found from cloud providers in the Intercloud.

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