PROPOSITION OF VOLUNTEER CLOUD COMPUTING

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1. Introduction

In this current era we can see a shift in how software and hardware are conceived, the end- goals are not the same as they used to be 2 decades ago. This can be attributed to the following, the fact that the Internet speed got a lot faster, by a factor of 1000 (based on a 56kbps connection in 1995, compared to a 50mbps connection today), but also because the hardware performance augmented at a similar pace. Initially in the pre-Internet era, software was written to be executed locally without any network interactions. Then in the genesis of the Internet, the objectives of software slowly shifted to access external resources, thus the apparition of the e-mail and the web-browser. Slowly as the connection bandwidths increased, there was an increased number of possible usage such as online games, content streaming, social-media, etc. Nowadays we can access fully virtualized computing environments within our web-browsers, and this takes us the very genesis of the Cloud Computing era.

1.1. **The Genesis of Cloud Computing.** The embodiment of Cloud Computing, namely the Internet of Things, can actually be traced back to the vision of J.C.R. Licklider of the *"Intergalactic Computer Network"* Licklider (1963):

> At this extreme, the problem is essentially the one discussed by science fiction writers: *"how do you get communications started among totally uncorrelated sapient beings?"*

This quote shows us the state of electronic tele-communication in the sixties, which is described as being fabric of fiction. There was military but also academic interest of providing an infrastructure that supports long-distance information processing. One of the most interesting idea of this memorandum is best conveyed in this following quote:

> When the computer operated the programs for me, I suppose that the activity took place in the computer at SDC, which is where we have been assuming I was. However, I would just as soon leave that on the level of inference. With a sophisticated network-control system, I would not decide whether to send the data and have them worked on by programs somewhere else, or bring in programs and have them work on my data. I have no great objection to making that decision, for a while at any rate, but, in principle, it seems better for the computer, or the network, somehow, to do that.

This very quote reflects the concept of offloading, not only of information or data, but of computation as a service. In other words that in some case it would be better, given the proper networking infrastructure, to offload the computation and send the data to be processed remotely.

Around the same time the concept of virtualization was being explored in the context of mainframe computers, in order to logically divide the resources between applications allowing them to run simultaneously. Throughout the years, the concept of virtualization broaden and now it is possible to run a complete Operating System on the application level. There is a direct correlation with the coming of the virtualization of hardware and the birth of the Cloud.

Cloud Computing is heavily influenced by the maturity of the Service-Oriented Architecture, and as we said earlier the evolution of the "Internet" with respect to the Web 2.0. That evolution of the Web from 1.0 to 2.0 is marked by the following characteristics, as cited in **?**: *[...] services, not packaged software, with cost-effective scalability; [...] data-centric w.r.t. Big Data; [...] users as co-developers; [...] harnessing collective intelligence; [...] leveraging long-tail effect through customer self-service.* We can observe a trend, the concept (web) services (rather then serving only static content) but also how the user becomes the central point of the network as a platform. This entails that components of the Web are becoming interactive services that can be contracted to responds to the users needs, via real-time aggregation of information using Big Data.

Thus the Cloud is the natural evolution of utilizing the network as a platform, through a Service-Oriented Architecture with respect to the natural evolution and maturity of the Web entailing the definition and wide-spread usage of mature Web-Services homogeneous interface (API). *Ipso Facto*, the adoption of pay-per-use business model for the offerings of Cloud Infrastructure.

1.2. **The Cloud.** There have been numerous attempts to try to give a concise or approximate picture of the Cloud Computing paradigm, with respect to its implementation and its different business models. One can review the following, **?**, **?**, **?**,**?**; to name a few. We feel that Mell and Grance (2011), **?** and **?**, provides a clear enough picture to represent the current Cloud ecosystem and we will use them to do so.

Cloud Computing infrastructure offers many advantages compared to the traditional on-premise infrastructure and it is why numerous companies consider outsourcing their IT infrastructure to an off-premise solution. Among the most important characteristics that this type of infrastructure offers, the NIST enumerates the following five Mell and Grance (2011):

(1) **On-demand Self-service** *Consumers are not required to interact with any representative of the provider to provision computing capabilities, rather it is automated through the provider's infrastructure.*

(2) **Broad Network Access** *Services are available over standard network infrastructure and through standard mechanisms, enabling different client platforms like cellphones, laptop, tablets, etc.*

(3) **Resource Pooling** *Providers offers a pool of Resources to different clients via a multi-tenant model, consisting of physical and virtual resources that can be assigned and re-assigned dynamically to cater to the clients demands. Clients are only aware, or able to choose the location of these resources with respect to pre-defined geographical regions.*

(4) **Rapid Elasticity** *Resources and services can be provisioned to scale to meet the fluctuations of the client's needs at any time, at any magnitude. The provider offers a seemingly unlimited number of services and resources to the client.*

(5) **Measured Service** *Resource usage can be monitored, controlled (optimized) and reported in a manner that proves transparent to both provider and consumer.*

In this modern day and age, among the major service providers of *The Cloud* we can find the likes of Google, Microsoft and Amazon, to name a few. They provide their services as a 5 different service models:

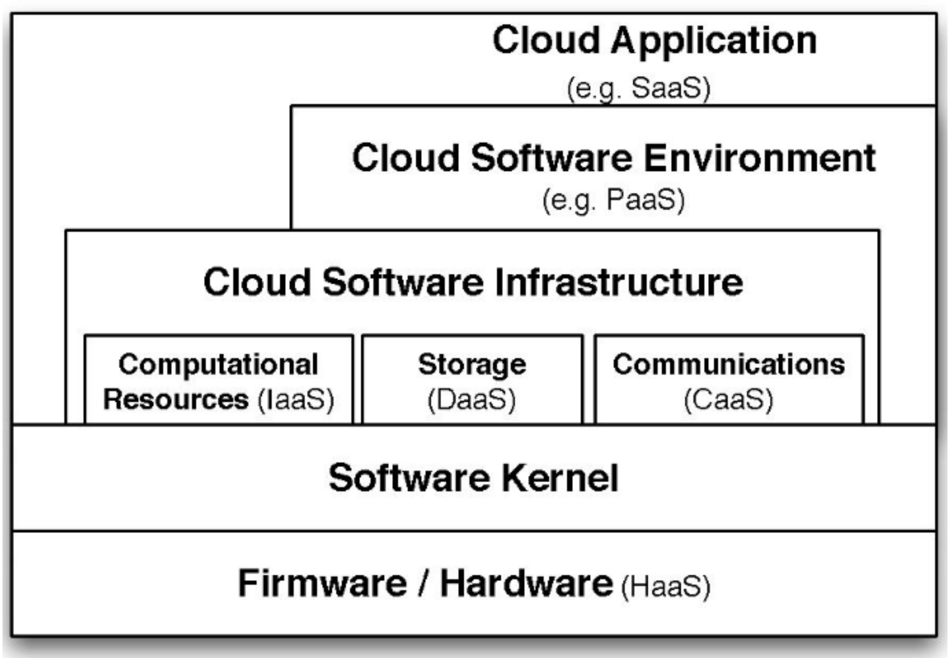


Figure 1. Ontological Representation of Cloud

Based on **?**, we can appreciate the categorization that emerged from their study of the major Cloud Service providers. We will briefly explain 3 of these categories in order to have a clearer picture of where this proposition resides in the grand scheme of the Cloud. In order to do so we will explore the question with respect of the Separation of Responsibilities, via a very concise graphical depiction Lewis (2011):

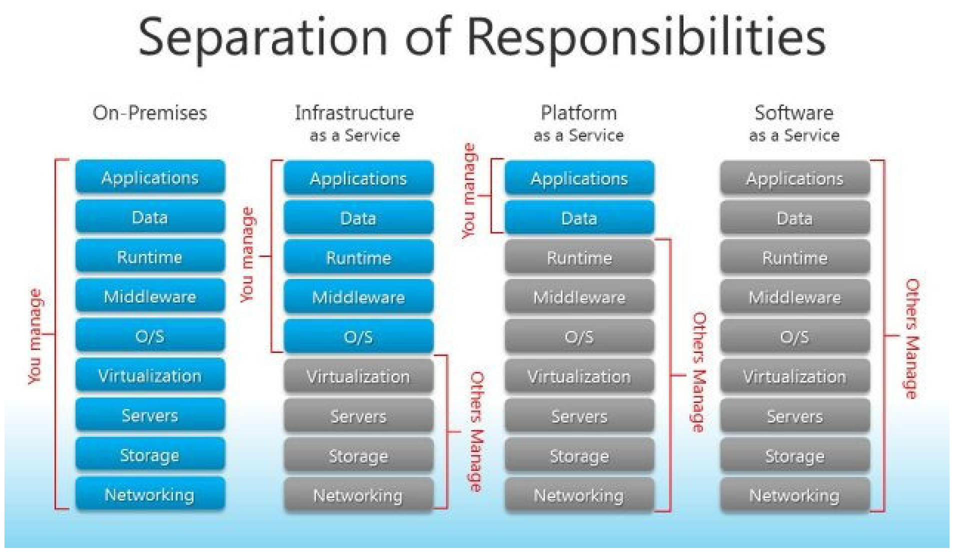


FIGURE 2. Cloud Services w.r.t. Responsibilities

1.2.1. *Infrastructure-as-a-Service (IaaS).* This service model provides, to its consumers, a virtualized environment that represents the full stack, from the hardware-level to the software-level, while taking care of the hardware management aspect. With this model, consumers can deploy any Operating System they wish, and as a matter of fact create the software environment that they deem most appropriate for their use. Since the hardware management responsibility is left out to the service provider, the client can easily augment or reduce the computing power at will to cope with the fluctuation of their demands. Amazon's Elastic Cloud Compute (EC2), or Windows Azure are part of the available IaaS solutions currently available.

1.2.2. *Platform-as-a-Service (PaaS).* This service model, if we refer to Figure 4, to its clients the ability of having to manage only the Application and Data aspect of the full-stack, everything else is managed and taken care of by its provider. Using such a service the client can focus on simply developing their application using the libraries, services and tools supported by the provider, and then deploy it onto the Cloud. Google's App Engine is perhaps one of the most popular example of this model.

1.2.3. *Software-as-a-Service (SaaS).* This service model, the consumer is provided with the capability to use applications (or software) running on the provider's cloud infrastructure, with little to no management capability, as depicted in Figure 4. From a user's perspective application are served as an atomic service, in the likes of Oracle ON DEMAND which offers on demand a customer relationship management application.

Finally we need to discuss the different *Deployment Models* that are offered in the Cloud eco-system. Relying again on the NIST Mell and Grance (2011) document, let's briefly present the 4 models:

(1) **Private Cloud** *This cloud infrastructure is meant to be used by a single organization, which can act also as a single provider or a providing partner with a 3rd party or solely as a consumer. Exclusivity is the key here.*

(2) **Community Cloud** *Very similar to the private cloud model, but in this case exclusivity of usage is shared among a community sharing common interests.*

(3) **Public Cloud** *This deployment model is aimed for open use by the general public, and the embodiment of this model's infrastructure is known as a Cloud Provider, such as Amazon, Google, Windows, etc.*

(4) **Hybrid Cloud** *This is the result of the combination of two or more distinct cloud infrastructure (which remain distinct to one another), but are combined using standardized or proprietary technologies to enable data and application portability.*

In the following subsection we will present a fifth deployment model, namely Volunteer Cloud Computing. But in order to provide the proper context for its emergence, lets take a brief look at Grid Computing and Volunteer Computing.

1.3. **Grid Computing.** A very extensive literature exist on this fairly recent paradigm (cite proper sources), and we can define it as being a form of Distributed Computing, where each node is ask to perform a different task, and the aggregation of those nodes workload constitutes the workload that needs to be perform in order to achieve the goal of (computationally) realizing its mandate. A

1.4. **Volunteer Computing.** The @Home paradigm or philosophy beautifully proves how this is realized, and let's look at a simple example the SETI@Home project.

1.5. **Volunteer Cloud Computing.** The concept of Volunteer Cloud Computing is a fairly new one, since as we can see there is no mention of it whatsoever in Mell and Grance (2011)Rimal et al. (2009). It revolves around user-provided resources as the building components of the cloud infrastructure, and typically takes place in a decentralized manner for which no single provider is designated, rather the collection of the participants form at the same time the provider and the consumers. One of the driving factors of this topological ideology is to harvest and make efficient use of distributed idling resources to provide a cloud infrastructure, with no real added cost.

In the following section we will review the literature to find out more about the position of Volunteer Cloud Computing with respect to the current deployment models in place, and if any implementation exists.

2. Related Work

2.1. **Cloud@Home.** The first real apparition of the term Volunteer Cloud Computing can be attributed to Cunsolo et al. (2009), in 2009 when they proposed the Cloud@Home paradigm. It can be described as a continuation of the @Home distributed computing effort and the merging of volunteer computing and Cloud computing. They propose an infrastructure in which it is possible for heterogeneous computing resources to be connected and to co-operatively provide a Cloud infrastructure, at a cost or for free. Thus this is a leap into monetizing the idle time of the consumer-grade computing resources, to provide a seamless Cloud experience to consumers. Although they provide a very detail analysis of the majority of the factors present in a Cloud architecture, little to no information was released after the publication of a series of more specific papers on the subject,. Last paper that was published, Distefano and Puliafito (2012), was indicating that they were actively working on an implementation of their proposed framework, but that was back in 2012. Thus, we will elaborate on what are the characteristics of this project, and try to understand why it seemed to have stop or at least why the driving factors seems less violent as they once were.

2.1.1. *Preliminaries.* The complete bibliography of the project span over 11 papers, which a couple of them are re-publications in different proceedings, journal, and/or conferences. The first paper Cunsolo et al. (2009), presents an overview of the scope and motivation, which we already discussed, but also presents a tentative architecture of what a it could become. What is very interesting here is the presentation of the *Issues, Challenges and Open Problems*, for which they define 6 aspects that will act a mind-map of the problems to tackle along the way, as well as a reminders of the realizability of some more open problems. Let's list them, as presented:

(1) **Resources and Service Management:** *Need for a mechanism that provides it.*
(2) **Frontend:** *Provide users with high-level service-oriented POV of the Cloud Infrastructure.*
(3) **Security:** *Cite different security concerns, not important for now.*
(4) **Reliability:** *Need for redundancy, and recovery mechanisms.*
(5) **Interoperability:** *Need to operate with other Cloud Infrastructures.*
(6) **Business Models:** *Need for QoS/SLA management for commercial Clouds, and also with the open volunteer Cloud framework.*

2.1.2. *Architecture.* Next they present an architecture that responds to these challenges (or requirements) partially or fully, but in a abstract fashion. A picture is worth a 1000 words, thus let's not babble on this much longer and present it:

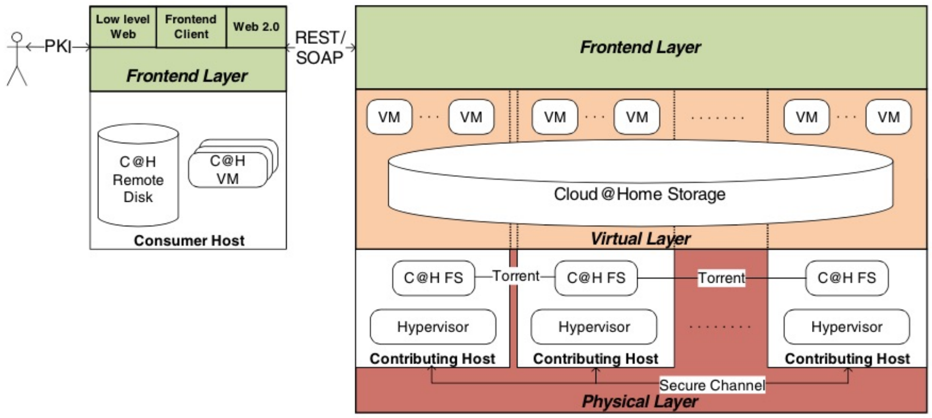


FIGURE 3. Cloud@Home Architecture

We can observe the three-tier approach to organize the architecture: *Frontend Layer*, *Virtual Layer* and the *Physical Layer*.
The **Frontend Layer** is the realization of the answer to the *Frontend* challenge that they proposed in their preliminary discussion of the project. In order to achieve it, they propose to split this layer into two parts, namely the *Server-side* and *Light Client-side*. We can see that they adopt a client-server approach from the user's perspective, and thus we can extrapolate that there is a hint for a centralized mean to deal with *Resource Management* (as a matter of fact in a later paper, namely Cunsolo et al. (2010) and Distefano et al. (2011) they explicitly express the need of a centralized entity w.r.t. Resource Management).
The **Virtual Layer** consist of a consequence to the *Frontend* challenge, or in other words *How to provide homogeneous perspective of a set of heterogeneous resources?* Their answer: through **Virtualization**, which enables us to discard the disparities within the different hardware offered by the participants. This virtualization will take place into what they call the *Execution Service*, and the persistency of the data will be ensured by the *Storage Service*. This service is analogous of the GoogleFS (file system) Ghemawat et al. (2003), which, in a nutshell split files into *chunks* of equal size, which are then distributed of different nodes called *Chunk Servers* (and replicated to ensure reliable storage). Finally there is a *Master Node* that catalogs all the meta-data about the data stored and simply indicate to the user which Chunk Server(s) possess the parts consisting the file requested, thus the user retrieve the chunks directly from the Chunk Server(s). This is a very naive simplification, but it serves to give an overview how such distributed file system can be implemented (in the context of this Cloud Infrastructure), and how from a user's perspective it resembles, as cited in Cunsolo et al. (2009): *a locally mounted remote disk*.
The **Physical Layer** act as the provider of physical resources to the layer above, but also it encompasses all that is required to manage those resources (locally). Also they note that it is here that the negotiation mechanisms, w.r.t. users contribution and request of

resources, should reside and by trickling down from the precedent layers it's policies should be enforced.
Finally this is a brief overview of the architecture that they propose for the Cloud@Home project, but nonetheless sufficient for now. It provides the mainlines to start an analysis, and if required we will in subsequent section to more specific aspect of this architecture as a mean of comparison to the architecture that we propose for our proof of concept.

2.1.3. *Brief Analysis.* We've presented the biggest and most important project w.r.t. a large-scale Volunteer Cloud Computing Infrastructure, now let's recapitulate the important points of this project. First they proposed to a marriage between volunteer and commercially available resources, and on this basis develop a business model that would give the ability to any user to monetize their volunteered resources. Secondly, they proposed a 3-tier architecture that would answer the major challenges that they identified, such as: offering a frontend that enables users to have a uniform homogeneous view of the cloud infrastructure; segregate the resources according to two services (Execution/Storage); and how to manage resources and services within a distributed infrastructure. Finally, we can observe that there is an intention of providing all types of delivery models: IaaS, PaaS, and SaaS.

2.2. **P2P Cloud System.** There was other notable effort conducted with respect to this concept, Babaoglu et al. (2012), albeit presented under a different category one of Peer-to-peer Cloud Architecture. The authors propose and describes the design and prototype implementation of a fully decentralized, P2P Cloud. They present the idea of Peer-to-Peer Cloud Computing, which consist of building a cloud out of independent resources that are opportunistically assembled. It could be built by assembling individual peers without any central monitoring or coordination component. It would provide on-demand scalability, access to computing and storage space with no single point of failure nor central management. Resources are added to the pool of resources simply by installing a software daemon on them. Their proposed implementation is advertised as a fully distributed IaaS Cloud infrastructure.
They differentiate themselves from Cloud@Home by putting emphasis on the fact that it relies on centralized components, while allowing users to contribute, (theoretically it isn?t required). Also, their architecture is fully de-centralized and it doesn't require any central bookkeeping service. Finally, they note that there is no known implementation to date of the Cloud@Home proposal.
The System Model they propose consists of nodes, and these nodes join by installing a software daemon. This software daemon presents two interfaces: a user interface and a node-to-node interface. The API that is exposed by the user interface is similar to conventional IaaS Cloud APIs (such as Amazon EC2 or S3). Nodes are managed by their respective owners in which case it offers no QoS guarantee. It goes for applications failures/crashes; the responsibility is reverted to the users (as would be the case for conventional IaaS Clouds).

2.2.1. *Architecture.* In this section we will briefly present the architecture of the P2PCS, and briefly analyze its key features.

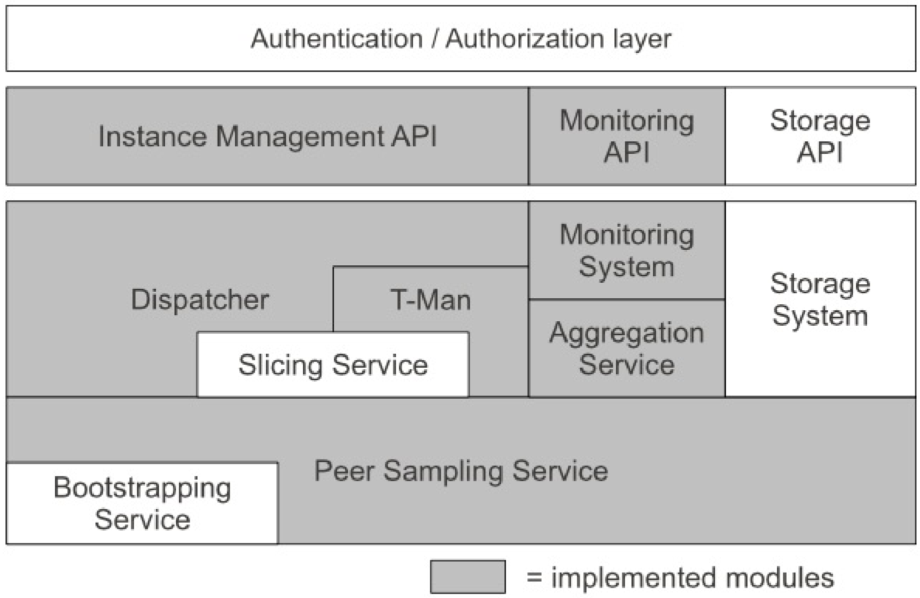


FIGURE 4. P2P Cloud System Architecture

We will briefly present each of the implemented modules (in gray). First the **Peer Sampling Service (PSS)** aims at providing each node with a list of peers to exchange messages with. They achieve this by maintaining an unstructured overlay over the set of peers. It can keep the overlay connected also in presence of churn, by using a simple gossip protocol. It uses a BootStrapping Service to gather an initial set of nodes, although it not implemented yet; the current implementation parses a text file with the IP addresses of the nodes.
Second is the **Slicing Service (SS)**, which is used to rank the nodes according to one or more attributes, it is also used to request slice of the whole cloud according to a user-defined criteria.
Third is the **Aggregation Service (AS)**, which is used to compute global measures using local message exchanges. It allows each peer to know system-wide parameters without the need to access a global registry.
Fourth is the **Monitoring System**, which is implemented on top of the AS, and it collects global system parameters and then provides them to the user. The MS API provides means to start and stop the display of run-time instance informations. In the current implementation it is used to display the topology of the network and the set of nodes of the slice a node belongs to.
Fifth is the **T-Man component**, which is used to create a overlay network with a given topology, and it is based on gossip protocols.

Sixth is the **Dispatcher**, which is responsible for handling the requests submitted by the user through the high level user interface and translate them into the appropriate low level gossip protocol commands which are sent to the other nodes.
Final is the **Instance Management API**, which contains all the functionalities to create and terminate instances, and also to provide means to list which resources are held by this user.
The implementation was done in Java, using the server-client paradigm.

2.2.2. *Brief Analysis.* It seems to be a dead project, since no updates were done or any changes were made since 2011. This is one of the driving factors of this inquiry. Did support for this project stop out of disinterest by the author, or did its tragic fate is the result of the coming to realization that it is not a appropriate architecture for the Volunteer Cloud Infrastructure?

The cornerstone of this architecture is the use of several gossip-based protocols to achieve such an infrastructure. We need thus to analyze this design decision, in order to assess its effectiveness with respect to particular problem that they are employed to solve.

2.2.3. *Tentative....* P2PCS - Gossip-based protocols for large dynamic networks

The Underlying incentive to use gossip-based protocol, in the context of V-Man is to maximize the optimality of the VM's distribution in large scale networked infrastructure, such as Clound infrastructure. The best visualization of this specific problem is the following, from **?**:

We can formally

3. Motivation

The motivation behind this proposal, is to analyze where past effort have not been as successful as expected. From this analysis, we wish to derive a design that take on past the shortcomings of the previous attempts and venture to propose a viable implementation for this paradigm, which to this day seems lacking.

3.1. **Service Model.** We need to situate where, within the already defined ontology of Cloud Computing, our effort will focus. This effort focuses on the Platform-as-a-Service model, conversely to Cunsolo et al. (2009) which attempted to propose a solution for all of the service models, and conversely to Babaoglu et al. (2012) that provides a solution w.r.t. the Infrastructure-as-a-Service model.
The driving factor to focus on a PaaS model, is that we intend to propose a solution that does not require any Hypervisor, and thus this solution will operate using Light Virtualization (in the form of containers and more precisely groups **?**). Rather than providing an infrastructure on which different VM can be deployed, we want to abstract this infrastructure by simply providing an environment on which code can be executed, regardless of the underlying infrastructure.
Although this implementation of the proof of concept targets the PaaS model, we will show

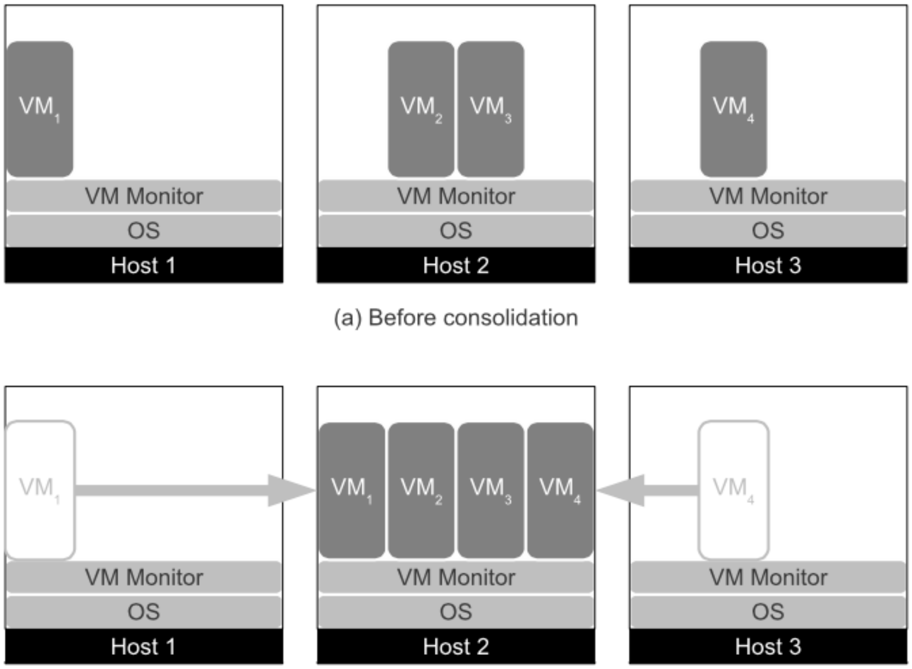


FIGURE 5. VM's aggregation problem

at the end that the underlying infrastructure that has been developed can be used in the context of SaaS also.

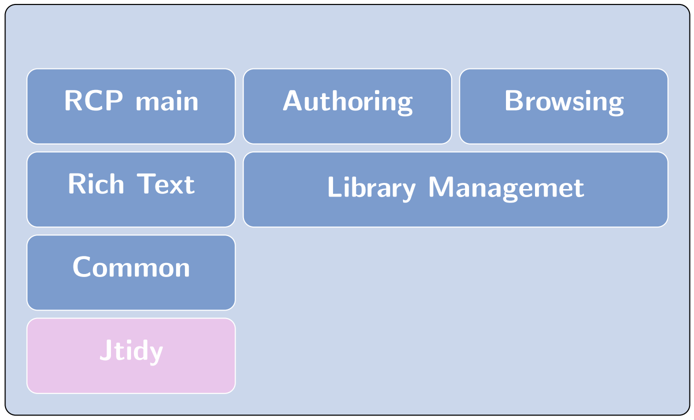
3.2. **Applications.** The C@H project presents

4. Contributions

In this section we will present our novel contributions with respect to previous related work.

5. Overview of the Architecture

In this section we presents a high-level overview of the architecture that we developed to achieve a fully de-centralized Volunteer Cloud Computing Infrastructure.



5.1. **Network Layer.** The network layer is responsible in aggregating the different geo-disparate resources and managing them under *churn*. Due to its highly dynamic nature, peer-to-peer infrastructures are required to tolerate frequent churn, and this can compromise their QoS unless the underlying networking structure is adequate (use of redundancy, replication, and other means to operate under failures). Churn rate, is used to represent the frequency of departure of participants with respect to the networking structure. Several options and techniques are available to deal with the characteristics of peer-to-peer networks, lets take a brief look at which one were adopted in the case of Cloud@Home and P2PCS; to help us make an educated decision on which technique is more appropriate in our case.

5.1.1. *Cloud@Home.* They admit the need of a centralized entity to deal with the problems that arises from utilizing distributed resources, thus they do not elaborate on how to overcome these specific problems. Rather they justify the need for some centralized authority to guarantee a decent level of QoS, in which they define *decent* through their business model. Finally, although they do use distributed heterogeneous resources, they compensate for their high volatility by proposing premium means to securing resources.

5.1.2. *P2PCS.* In the context of P2PCS, they point out the fact that they propose a *fully de-centralized peer-to-peer infrastructure* compared to their counterpart (C@H). They claim to achieve this via several gossip-based protocols, and thus we must analyze their claims and justification to see if we should use a comparable approach in our architecture.

First let's introduce a very elementary definition of a gossip-based protocol

References

Babaoglu, Ozalp, Moreno Marzolla, and Michele Tamburini (2012), "Design and implementation of a p2p cloud system." In *Proceedings of the 27th Annual ACM Symposium on Applied Computing*, 412–417, ACM.

Cunsolo, Vincenzo D, Salvatore Distefano, Antonio Puliafito, and Marco Scarpa (2009), "Cloud@ home: Bridging the gap between volunteer and cloud computing." In *Emerging Intelligent Computing Technology and Applications*, 423–432, Springer.

Cunsolo, Vincenzo D, Salvatore Distefano, Antonio Puliafito, and Marco Scarpa (2010), "Open and interoperable clouds: The cloud@ home way." In *Cloud Computing*, 93–111, Springer.

Distefano, Salvatore, Maria Fazio, and Antonio Puliafito (2011), "The cloud@ home resource management system." In *Utility and Cloud Computing (UCC), 2011 Fourth IEEE International Conference on*, 122–129, IEEE.

Distefano, Salvatore and Antonio Puliafito (2012), "Cloud@ home: Toward a volunteer cloud." *IT Professional*, 14, 27–31.

Ghemawat, Sanjay, Howard Gobioff, and Shun-Tak Leung (2003), "The google file system." In *ACM SIGOPS Operating Systems Review*, volume 37, 29–43, ACM.

Lewis, Brian (2011), "Separation of responsibilities." Taken from http://mythoughtsonit.com/2011/04/infrastructure-as-a-service-platform-as-a-service-software-as-a-servicetake-a-look-at-the-management-stack, Consulted: November 19th 2014.

Licklider, Joseph CR (1963), "Memorandum for members and affiliates of the intergalactic computer network." *Apr*, 23, 350–1.

Marzolla, Moreno, Ozalp Babaoglu, and Fabio Panzieri (2011), "Server consolidation in clouds through gossiping." In *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2011 IEEE International Symposium on a*, 1–6, IEEE.

Mell, Peter and Tim Grance (2011), "The nist definition of cloud computing." x.

O'reilly, Tim (2007), "What is web 2.0: Design patterns and business models for the next generation of software." *Communications and Strategies*, 65, 17–37.

Panzieri, Fabio, Ozalp Babaoglu, Stefano Ferretti, Vittorio Ghini, and Moreno Marzolla (2011), *Distributed computing in the 21st century: Some aspects of cloud computing*. Springer.

Rimal, Bhaskar Prasad, Eunmi Choi, and Ian Lumb (2009), "A taxonomy and survey of cloud computing systems." In *INC, IMS and IDC, 2009. NCM'09. Fifth International Joint Conference on*, 44–51, Ieee.

Vaquero, Luis M, Luis Rodero-Merino, Juan Caceres, and Maik Lindner (2008), "A break in the clouds: towards a cloud definition." *ACM SIGCOMM Computer Communication Review*, 39, 50–55.

Youseff, Lamia, Maria Butrico, and Dilma Da Silva (2008), "Toward a unified ontology of cloud computing." In *Grid Computing Environments Workshop, 2008. GCE'08*, 1–10, IEEE.

Zhang, Qi, Lu Cheng, and Raouf Boutaba (2010), "Cloud computing: state-of-the-art and research challenges." *Journal of internet services and applications*, 1, 7–18.