The Cloud@Home Project: Towards a New Enhanced Computing Paradigm*

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Abstract. Cloud Computing is emerging as a promising paradigm capable of providing a flexible, dynamic, resilient and cost effective infrastructure for both academic and business environments. The aim of this project is to create a new Cloud paradigm, "Cloud@Home", in which both the commercial/business and the volunteer/scientific viewpoints coexist. The Cloud@Home infrastructure has to be able to provide adequate resources to satisfy user requests also taking into account QoS requirements. The goal of the project is to design, to implement and to test on real case studies a complete middleware able to demonstrate the feasibility of the Cloud@Home vision. In this paper we try to summarize the the Cloud@Home project, identifying the tasks in order to implement the Cloud@Home middleware.

1 Introduction and Motivations

Cloud computing is a *service-centric*, distributed computing paradigm in which all capabilities and resources (usually geographically distributed) are provided to users *as a service*, to be accessed through the Internet without any specific knowledge of, expertise with, or control over the underlying technology infrastructure that supports them. It offers a user-centric interface that acts as a unique, user friendly, point of access for users' needs and requirements. Moreover, Cloud computing provides *on-demand service provision*, *QoS guaranteed offer*, and *autonomous system* for managing hardware, software and data transparently to users [9].

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In order to achieve such goals it is necessary to implement a level of abstraction of physical resources, uniforming their interfaces and providing means for their management, adaptively to user requirements. This is done through *virtualizations*, *service mashups* (Web 2.0) and *service oriented architectures* (SOA). The development and the success of Cloud computing is due to the maturity reached by such technologies.

A great interest on Cloud computing has been manifested from both academic and private research centers, and numerous projects from industry and academia have been proposed. In commercial contexts, among the others we highlight: Amazon Elastic Compute Cloud, IBMs Blue Cloud, Sun Microsystems Network.com, Microsoft Azure Services Platform, Dell Cloud computing solutions. There are also several scientific activities, among the others: Reservoir [7], Nimbus-Stratus-Wispy-Kupa [8], OpenNEbula [2], Eucalyptus [4], OCCI [5], Open Cyrrus [3] and Open QRM [6]. All of them support and provide an on-demand computing paradigm, in the sense that a user submits his/her requests to the Cloud that remotely, in a distributed fashion, processes them and gives back the results. This client-server model well fits aims and scopes of commercial Clouds: the business. But, on the other hand, it represents a restriction for scientific Clouds, that have a view closer to *Volunteer computing*. Volunteer computing (also called *Peer-to-Peer computing*, *Global computing* or *Public computing*) uses computers volunteered by their owners, as a source of computing power and storage to provide distributed scientific computing [1].

We believe the Cloud computing paradigm is applicable also at lower scales, from the single contributing user, that shares his/her desktop, to research groups, public administrations, social communities, small and medium enterprises, which make available their distributed computing resources to the Cloud. Both free sharing and pay-per-use models can be adopted in such scenarios. We therefore propose a more “democratic” form of Cloud computing, in which the computing resources of single users accessing the Cloud can be shared with the others, in order to contribute to the elaboration of complex problems. Since this paradigm is very similar to the Volunteer computing one, it has been named *Cloud@Home*. Both hardware and software compatibility limitations and restrictions of Volunteer computing can be solved in Cloud computing environments, allowing to share both hardware and software resources or *services*. The Cloud@Home paradigm could be also applied to commercial Clouds, establishing an *open computing-utility market* where users can both buy and sell their services.

2 Aims and Goals

The Cloud@Home paradigm is inspired to the Volunteer computing one. In this new paradigm, user’s hosts are not passive interfaces to Cloud services anymore, but they can interact (for free or by charge) with other Clouds. Fig. 1 depicts the Cloud@Home reference scenario, identifying the different stakeholders characterized by their role: consuming and/or contributing. Arrows outgoing from the Cloud represent consuming resources, from which a Cloud@Home client submits its requests; otherwise, arrows incoming to the Cloud represent contributing resources providing their services to Cloud@Home clients. Therefore, infrastructure providers, datacenters, Grids, clusters, servers, till desktops and mobile devices can both contribute and consume.

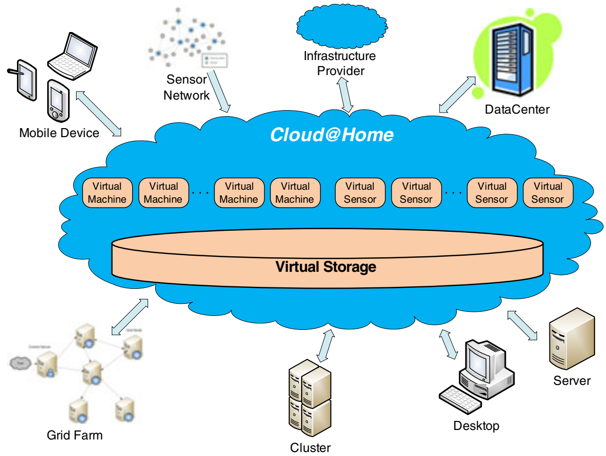

Fig. 1. Cloud@home Reference Scenario

In fact, we believe that the Cloud@Home paradigm is widely applicable, from research groups, public administrations, social communities, SMEs, which make available their distributed computing resources to the Cloud, till, potentially, the single contributing user, that autonomously decides to share his/her resources.

According to the Cloud@Home vision, all the users can be, at the same time or in different moments, both clients and active parts of the computing and storage infrastructure. A straightforward application of this concept to the world of mobile devices is not so much useful, because of the limited computing power and storage capacity that are available on such nodes. Still, an active participation of the mobile nodes to the cloud services can be opportune if we start considering as resources, not only computing and storage, but also the peculiar and commonly available peripherals/sensors available on mobile phones (e.g., camera, GPS, microphone, accelerometer, etc) or other devices such as the nodes of a sensor network. In other words Cloud@Home, besides virtualizing the computing and storage resources, aims at virtualizing also the sensing infrastructure. Such infrastructure, consistently with the other functionalities, has to be accessed as a service (*sensor as a service*, SEAAS). According to this perspective, in Fig. 1 mobile devices are considered as both contributing and consuming resources, since they can provide their sensors to Cloud@Home and/or they can access the Cloud for submitting their requests as common clients, respectively.

The project framework will be based on a Cloud@Home software system which provides readily available functionality in the areas of directory/information services, security and management of resources. In order to implement such a form of computing the following issues should be taken into consideration: resources management, user interface, security, accounting, identity management, virtualization; interoperability among heterogeneous Clouds; business models, billing, QoS and SLA management. A possible rationalization of the tasks and the functionalities the Cloud@Home middleware has to implement can be performed by considering the layered view shown

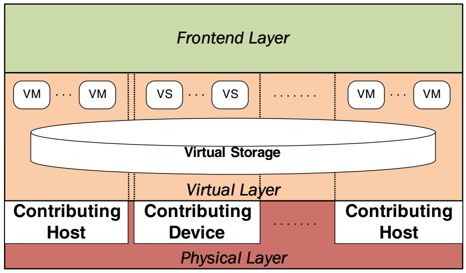

Fig. 2. Cloud@home Layered Model

in Fig. 2. Three separated layers are there identified in order to apply a separation of concerns and therefore to improve the middleware development process:

- The Frontend Layer that globally manages resources and services (coordination, discovery, enrolment) implements the user interface for accessing the Cloud (ensuring security reliability and interoperability), and provides QoS and business models and policies management facilities.
- The Virtual Layer that implements a homogeneous view of the distributed Cloud system offered to the higher frontend layer (and therefore to users) in form of two main basic services: the execution service that allows to set up a virtual machine, and the storage service that implements a distributed storage Cloud to store data and files as a remote disk, locally mounted or accessed via Web. Virtual Sensors (VSs) provide the access points to the sensing infrastructure.
- The bottom Physical Layer that provides both the physical resources for elaborating the requests and the software for locally managing such resources. It is composed of a "cloud" of generic nodes and/or devices geographically distributed across the Internet.

3 Insights

Fig. 3 identifies and groups all the tasks of the Cloud@Home project into six blocks: frontend, SLA, QoS, service composition, security management and virtualization. In the following we provide some details on them.

3.1 Frontend

The user frontend provides tools for Cloud@Home-user interactions. It collects and manages the users' requests issued by the Cloud@Home clients. All such requests are transferred to the underlying layer for processing. The frontend is made up of three subtasks: *mobile access*, *Web access* and *Web service access*. The mobile access provides user interfaces specifically customized for being accessed by devices with small screens and limited input capabilities. The Web access provides all mechanisms and tools for implementing the Web access to the Cloud@Home infrastructure. The Web service access instead focuses on the interface to Web services of the Cloud@Home infrastructure.

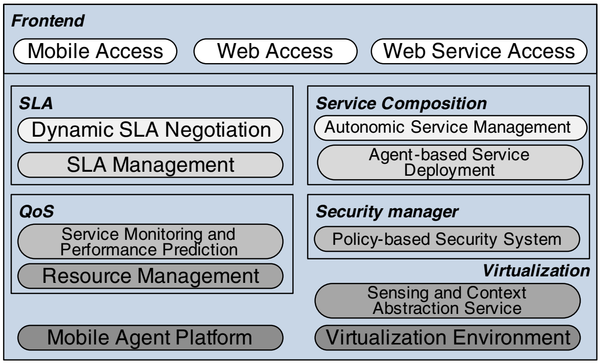

Fig. 3. Cloud@Home infrastructure middleware development tasks allocation

3.2 SLA and QoS

The SLA block will take into account the high dynamicity of the Cloud@Home volunteer context, so it is split into: *dynamic SLA negotiation* and *SLA management*. The dynamic SLA negotiation module provides a framework for the negotiation of non-functional parameters in complex environments of resource and service sharing, composition and virtualization. The SLA management system is responsible for the service lifecycle. This includes service definition, deployment, management, monitoring, compliance and termination. Users require services which are incorporated within contracts containing business terms with no reference to raw resources. The system manages the service by automatically configuring and deploying it. In order to meet the contract terms, the system will monitor SLAs and take any opportune action, such as re-configuration, re-location or resource re-allocation.

One of the Cloud@Home project aims is to deal with QoS in both open and commercial environments. In this context several issues concerning the QoS and SLA management have to be adequately considered, faced, and solved, as mentioned above. Resource optimization within the Cloud becomes a key requirement.

The Cloud@Home project QoS activity is organized in two sub-activities: *service monitoring and performance prediction* and *resource management*. The service monitoring and performance prediction will be carried out at three different levels:

– **Application Level:** the mobile agent platform will offer a set of a monitoring agents, able to move between the virtual resources collecting performance indexes;
– **Platform Level:** both SLA Engine and CHASE will collect information from the monitored resources using their proprietary solutions;
– **Resource Level:** (some of) partecipating resources will be enriched with monitoring tools that can be remotely interrogated.

3.3 Service Composition

Cloud@Home will exploit CHASE (Cloud@Home Autonomic Service Engine) in order to manage resources: the main goal of CHASE is to schedule, allocate, and possibly migrate the services making up the applications running in Cloud@Home in an "intelligent" way, making it possible to obtain given QoS indexes and to fulfil SLA agreed upon when applications are submitted. These features are provided automatically, self-tuning and self-optimizing the hardware/software system under dynamic and possibly rapidly-changing resource usage conditions. CHASE achieves this results using simulation based techniques in conjunction with optimization algorithms, avoiding the brute-force exploration of the possibly large space of solutions.

3.4 Security Management

In order to design a prototype of a security infrastructure to support the use cases of the Cloud@Home project, the following issues will be faced:

- *Protection level agreement*. The agreement between a service provider and a client normally contains guarantees over non functional requirements, reflecting the client business objectives. These objectives determine the Quality of Service (QoS) that the provider should guarantee during service provisioning.
- *Policy specification languages*. Our objective in this area is to analyse several languages for the specification of security policy and to identify the most suitable for the specification of cloud security policies, by possibly extending existing proposals, that do not provide some critical features.
- *Security-aware resource/service discovery and selection*. The discovery and selection of services/resources in Cloud@Home will take into consideration security among the main requirements. Thanks to the specific security policy adopted by a provider, a potential client will be able to explicitly describe and to impose constraints on security aspects, which will be accounted for in the process of discovery and resource selection.

3.5 Virtualization

The virtualization of the Cloud@Home infrastructure is one of the most important task to implement. All the Cloud@Home computing, storage and sensors resources have to be virtualized in order to be provided as a service. Thus, the activity is organized into three main sub-activities: *sensing and context abstraction service*, *virtualization environment* and *mobile agent platform*.

The sensing and context abstraction service (SCAS) implements the virtual sensor concept, and provides sensing and context information to applications executed within the Cloud.

In the considered scenarios, the context could also include the nature of the device, the quality and availability of wireless connection, the residual power, the physical location of the user. To protect the users from unwanted accesses to their data, the system will include mechanisms useful to specify and enforce access policies.

The virtualization environment provides solution to the problem of heterogeneous hardware and software (OS, libraries, compilers, etc.) by means of virtualization techniques, based on Virtual Machine Monitors such as VMware, VirtualBox, Xen, Qemu and so on. They create virtual execution environments that satisfy individual requirements in terms of memory, disk space, operating system, adapting the runtime environment to the application instead of adapting the application to the runtime environment.

Similar problems must be tackled in organizing and managing storage resources. In fact it is necessary to provide an adequate architecture able to split data in chunks and to store such chunks into the distributed disks. Problems of data security such as confidentiality and integrity, have to be adequately considered and solved in the implementation of the virtual storage environment system.

In order to face the flexibility of virtualized resources, the Cloud@Home platform is enriched with a mobile agent platform which offers a flexible programming paradigm and adaptable services. The mobile agent platform will be adopted to easily deploy new application on the virtual resources, to perform application level monitoring, to develop brokering services and to build up customized interfaces between users and the platform.

4 Case Studies

The Cloud@Home middleware will be tested by using some real reference scenarios, involving organizations external to the project, such as Oracle, Insirio, IBM, and Inquadro, in order to highlight the needs that could decisively encourage its adoption. The first one refers to the utilization of complex enterprise software systems requiring specific hardware resources. Since one of the main source of costs and complexity for companies is related to expand, to tune and to optimize the hardware resources in order to effectively satisfy high demanding, domain-specific technical software and to ensure adequate productivity levels, we consider the utilization of complex enterprise software systems requiring specific hardware resources as the first use case of Cloud@Home. The use of the Cloud@Home technology allows to adequately exploit the company computing resources, which are sometimes distributed over several sites, to meet the demands of the mentioned software, building a private Cloud. Cloud@Home also enables to create, customize and use resources and services running in remote interoperable Clouds. In this scenario powerless terminals can be used to implement remote-desktop connections with both computing and storage delegated to the Cloud. Optimized management of hw/sw platforms and services, simpler monitoring and maintenance, QoS and security provision are some of the further benefits inherent in such approach.

A volunteer computing scenario is instead identified in the second case study, which intends to set up a federated Cloud@Home environment, composed of “local” Clouds located in each research group. This case study intends to highlight the free-sharing and volunteer contributing vocation of Cloud@Home. Each research group involved in the project will build its own local Cloud, starting from the available resources and services in its organization. The Clouds thus created will be federated, implementing a unique Cloud@Home environment, also open to individual contributors. In this way we will set up a significant testbed for experimenting the Cloud@Home middleware and all its capabilities (interoperability, QoS, security, resource management, etc) and scenarios (heterogeneous nodes, wireless devices, ubiquitous and pervasive computing, location based services, etc).

The third use case is mainly focused on mobile environments, in which we imagine the following scenario: a cloud computing system hosts an application dedicated to the management of traffic lights and parking lots of an urban area. Users equipped with mobile phones could voluntarily share their positioning information with the management application. Information gathered in this way could be used to dynamically compute more efficient vehicle routing strategies. The presence of supporting and shared mechanisms for the abstraction of sensing information within the cloud infrastructure foster the reuse of available data in different applications.

5 Conclusions

In this paper we proposed an innovative computing paradigm that merges volunteer contributing and Cloud approaches into Cloud@Home. This proposal represents a solution for building Clouds starting from heterogeneous and independent nodes, not specifically conceived for such a purpose.

In this way Cloud@Home opens the Cloud computing world to scientific and academic research centers, as well as to communities or single users: anyone can voluntarily support projects by sharing his/her resources. On the other hand, it opens the utility computing market to the single user that wants to sell his/her computing resources. To realize this broader vision, several issues must be adequately taken into account: reliability, security, portability of resources and services, interoperability among Clouds, QoS/SLA and business models and policies.

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