From Grids to Clouds: A Collective Intelligence Study for Inter-cooperated Infrastructures

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Abstract – **Recently, more effort has been put into developing interoperable and distributed environments that offer users exceptional opportunities for utilizing resources over the internet. By utilising grids and clouds, resource consumers and providers, they gain significant benefits by either using or purchasing the computer processing capacities and the information provided by data centres. On the other hand, the collective intelligence paradigm is characterized as group based intelligence that emerges from the collaboration of many individuals, who in turn, define a coordinated knowledge model. It is envisaged that such a knowledge model could be of significant advantage if it is incorporated within the grid and cloud community. The dynamic load and access balancing of the grid and cloud data centres and the collective intelligence provides multiple opportunities, involving resource provisioning and development of scalable and heterogeneous applications. The contribution of this paper is that by utilizing grid and cloud resources, internal information stored within a public profile of each participant, resource providers as well as consumers, can lead to an effective mobilization of improved skills of members. We aim to unify the grid and cloud functionality as consumable computational power, for a) discussing the supreme advantages of such on-line resource utilization and provisioning models and b) analyzing the impact of the collective intelligence in the future trends of the aforementioned technologies.**

Keywords – Grid computing; Cloud computing; Collective Intelligence; Mobility Agents

I. INTRODUCTION

Grid computing is defined as the combination of several distributed resources from multiple Virtual Organisations (VOs) for solving a single problem, which is usually a scientific or technical problem [13]. A VO is a group of members whose resources function as a unit. This form of distributed computing tends to be distinguished from the conventional systems, by offering a heterogeneous environment of loosely coupled connections. On the other hand, over recent years the notion of clouds has proven to be a model that has had significant commercial success [15]. The commercialized distributed resources are spread across the internet and are available for purchase from users by offering capabilities of resource management and provisioning. It may be noted that the concepts behind grid and clouds can be described from a technological perspective as a novel way for a) achieving inter-collaboration among several users or distributed resources (from the grid viewpoint) and b) a high quality and on-demand resource provisioning model involving various stakeholders (from the cloud viewpoint). In other words, clouds can utilise enterprise resources by serving multiple users across an inter-cooperated grid environment. Fundamentally, the service-oriented infrastructures of both technologies aim to provide a virtualization model of entities as services and the seamless interactions and integration of these services. In terms of virtualization we define everything that can be virtualized in any environment separated by the underlying location and spread across the internet. In general, cloud technology is derived from grid, virtualization, and utility computing [14], [18]. Utility computing is a priced service of server's capacity that is accessed over the grid [15]. In any case, all the aforementioned technologies collaborate with each other, aiming to offer a user resource over the internet.

One of the major advantages of on-demand technologies, e.g., cloud, utility and virtualized computing is that by a subscribing cost users don't have to deal with hardware and software licences, versions, incompatibilities, failures and maintenance. On the other hand, the complex requirements of users, which include subscription cost versus the usage, are drawbacks of clouds. In general, several resources including hardware and software can be delivered to users with different needs. The clients that utilize the resources may be categorized as uncomplicated consumers, business and enterprises as well as multi-tenancy users. So, the different requirements raise several complications and complexities. A simple example is that, companies are reluctant that their data are outside their firewall. From the user perspective, cloud participants want to be charged only for the amount of resources that they use. However, cloud and grid, have proven to be secure, reliable and scalable and the resources which are put to use according to actual requirements have an efficient load balancing feedback mechanism [18]. In the case of uncertain or pre-specified boundaries the complexity of users' requirements may be approached by a more generalised model [1]. It is apparent that the actual capabilities of several resources are dependent on how grids or clouds are employed. Since clouds are related to usage concepts and grid is relative with technological concepts, the collective intelligence goes one step further with on-demand resource provisioning. This may eliminate and

 ISBN: 978-1-61208-101-4

remove the need to over-provision in order to meet the demands of millions of users by evaluating their knowledge.

The collective intelligence is a paradigm suggesting a new source of empowerment by monitoring the exchanged intelligence among cloud and grid users. This is when data, software applications or computer processing power are accessed by a cloud of online resources and can be reused to support decision making and team building [17]. The digital communication and sharing of data can be collected and be analysed by a perception model. The collective learning may offer (in the future) grids and clouds that employ a creative method by evaluating current data and offering new knowledge to a neighbourhood of users. The inter-cooperation model among unknown members may significantly improve the production of collective intelligence knowledge, and especially in a competitive and sharp environment.

In the following sections, we discuss the motivation of the study (Section 2), and the related work and definition of similar technologies (Section 3). We then continue by introducing the inter-cooperation model of grids and clouds and the collective intelligence application (Section 4, 5). We then use this to discuss a case study of clouds and grids as a means of forming the collective intelligence method (Section 6). Finally, we conclude our study with the future work section and the proposed challenges part (Section 7).

II. Motivation

Various approaches and definitions of clouds exist [14, 18], all conclude that cloud is comprised of grid, virtualization and utility computing notions [13]. Each of these technologies may be seen as a set of layers that encompass the cloud, which could exploit user behaviour and draw collective intelligence. In a broader view, a cloud can be seen as a customized grid. The members forming the cloud can access resources, solve problems similar to grids but in a more structured, scalable and personalised management manner; as well as by charging a subscription cost. A grid VO may offer the cloud a geographically distributed environment formed under a common policy management scheme either centralized, or de-centralized. Consequently, VO members may utilize resources to solve VO defined problems.

It is common that within a VO, members or resources perform interactions based on two different perspectives. Firstly, the centralized management system monitors the procedure and is responsible for the service negotiation. Secondly, the decentralized control system of autonomous acting VO members. A typical VO will have access to many facilities which are not owned and managed by the VO [13]. These facilities may be multi-participant communities, resources or VOs. Mutually, in a VO, a universally agreed model of policies has been adopted by each individual, and determines the accessibility factor of each resource.

From the viewpoint of the decentralized solution, the mobility agents' paradigm offers a novel technology of achieving communication among loosely coupled connections of multi-institutional VOs [4]. By considering the grid as a coordinated problem solving approach in dynamic environments, agents may be the means of acting dynamically and autonomously whilst performing migration to any inter-connected member [10]. Moreover, collected knowledge among cloud or grid members may be organised and shared by utilizing the intelligent agent model. The essence of the aforementioned standard may be achieved by using the framework of *Self-led Critical Friends* (SCF) which fills the gap between consumer's providers and enables inter-operation of nodes from various grid VOs [6], [7]. The ultimate goal is to extend the conventional grid's bounded VO topology to a wider dynamic community established upon SCFs knowledge of members from different grid and clouds domains also known as *Critical Friends Community* members.

Originally, the SCFs act as intermediate stations in the communication between multiple grids by providing an extended environment. SCFs may act among a cloud of users, so the collective intelligence may be extended. Essentially, an expanded intelligent agent takes information about their interest, problems and behaviour and recommends to users, and companies, solutions and information for improving services as well as proposing new forms of social applications. As typical to Web 2.0 applications an online community' interests and activities can be captured by software APIs of any device and give profit to stakeholders; even if they are providers, resellers, adopters or users [8]. The SCFs could fulfil the gap among resource consumer and providers by expanding the community boundaries.

III. Related Technologies and Definitions

The related technologies are slightly different in the use of terminology and it is hard to be distinguished as they usually offer the same type of services [14]. For that reason, we suggest that shared resources should be separated in the following ways according to their service orientation:

a) The Software as a Service (SaaS) framework provides specific cloud capabilities concerning software functionalities available through the internet. Each individual can access the applications from any device [18]. Examples include commercial SaaS, project online tools and customer relationship management tools.

b) The Hardware as a Service (HaaS) framework, also known as infrastructure as a service (IaaS) provides computational power and resources [18]. This type of cloud is similar to the virtualization environments in which applications are separated from infrastructures and computer capacity is shared over the web.

Similarly, service orientation clouds can be also separated according to their deployment orientation [18]. Firstly, there are private and public clouds whose functionality is to behave as intra and inter collaborated environments. In both scenarios, clouds are similar to private and public VOs. It is also essential that specific measures and policies are applied by a VO management control system. Secondly, there are community clouds which are typically similar to grid technology, and can aggregate public clouds or dedicated resource infrastructures.

We can hence separate clouds according to their service or deployment orientation; however, the data centres which initiate cloud capabilities may consider, from either perspective, that a collective intelligence concept can be utilized. It should be mentioned that members of grid or clouds can behave as resource owners as well as resource consumers, so they have to respect policies and credentials of VOs or VO members. From the view of a resource consumer, their requirements may be organized as follows [16]:

a) May belong to one or more VOs or clouds
b) May have several roles and actions
c) May control internal roles, actions and memberships
d) May assign priorities to members jobs
e) May list resources and internal knowledge in a metadata snapshot profile
f) May assign special credentials to specific members
g) May enable or not authentication to other members
h) May select or deselect roles and actions

On the other hand the requirements from the perspective of the resource providers are organised as follows:

a) VOs or clouds should control resource participation
b) VOs or clouds should specify their own policies and resource authentication
c) VO or clouds should have a consistent authorization process
d) VO or clouds must be able to specify requirements on any resource for specific roles.
e) Within a VO or a cloud a common policy model should be agreed

Not all of the above requirements are necessary attributes of grid or cloud members. However, it is the basis for a collective intelligence model of policies and strong communication links. Resource providers and consumers should support such infrastructures aiming to improve performance and profit.

Overall, grid and cloud environments provide a way to implement future applications about monitoring knowledge and improving software intelligence. It is evident that the analysis of requirements is a difficult aspect of such designs. Finally, an intelligent agent model may assist in the consolidation of a requirement scheme, based in a secure and elastic scalability model. In order to organize such a strategic model, it is crucial to identify the accessibility factor of each VO. In this direction, we suggest that it is necessary to store agreement protocols within each member's public profile. We define this storage as the *metadata snapshot profile*, which is available upon request from any member. The profile stores data about a member's potential. In other words, it is a unique intelligence storage place for each individual. By viewing it as such, we can construct several metadata snapshot profiles, and realize a collective intelligent model of inter-cooperating members.

IV. CO-OPERATING GRIDS AND CLOUDS

It has been proposed that "*the real and specific problem underlies the grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations*" [10]. In other words, they suggest that resource sharing must be synchronized clearly negotiated and defined among resource owners, consumers and providers. Finally, the multi-institutional statement refers to a collaborating environment of several VOs.

It is very important that the resource discovery method of resources fulfils the needs of resource consumers and providers. The resource discovery method in such uncertain environments starts when a member requests information from the metadata snapshot profile of any connected grid or cloud participant. The profile contains various data but initially we are seeking for the addresses of well known and trusted nodes. In figure 1 we assume that n_1 can access n_2 as well as any other member of VO_1. However n_2 contains a new address of the related (and inter-connected) member b_1, so n_2 assigns a reference contract to the SCF contract and updates the profile of n_1. At this stage n_1 is capable of establishing a connection with b_1. However n_1 then requests information from b_1 as they are both trusted members so they follow the same procedure and the new updated profile of n_1 contains the addresses of all members of VO_2. The procedure continues and all members from both VOs have access to any resource available to the mutually interconnected VOs.

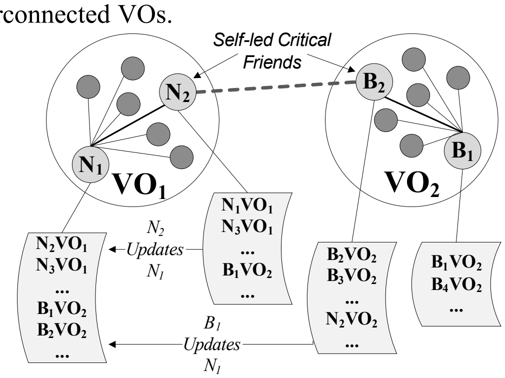

Figure 1: The SCFs communication model

In such situations mobile agent functionality may serve the aforementioned model by traversing a specific route. By moving from one location to another it visits all individuals of a VO. Each time an agent moves to a specific location it carries internal data about physical resources and internal knowledge. During their route traversal agents are capable of visiting different platforms and by collecting and updating internal data as they continue the journey. In other words, the collective intelligence carries the internal data from member to member as a list of addresses, capacities and information such as beliefs and desires. This has the potential for stakeholders, including providers, resellers, and users to utilize a users' demands and requests to identify solutions for well defined problems in a fast and reliable manner.

V. Collective Intelligence

The goal of collective intelligence is to harness the system of self-centred grids, clouds and agents to secure a sustainable relationship, so that coordinated individuals may solve problems more efficiently [5], [9]. In general, collective intelligence of unified and synchronized grid and cloud communities can offer significant advantages. A clear example in nature is the ants; an individual ant is not very powerful, but a colony of ants can achieve significant results. Collective intelligence can be found in many systems, and it is known as swarm intelligence, ant colony optimization and neural networks. So, we may describe such a method as collective intelligence, which can be seen as an infrastructure or environment in which individuals can do simple operations, however by working they are able to perform and solve complex problems. It is almost certain, that the complexity of the aforementioned environments is high as they are formed from different resource consumers and providers connected in loosely coupled groups. In our vision, intelligent agents fulfil the gaps of security and transparency in grid or cloud members' communication. So, their characteristics are that they:

a) Present a digital community with information exchange capability as well as purchasing, selling, storing, transmitting and processing means
b) Collect information about other member's potentials
c) They categorise facts, comments and opinions of members
d) Offer a secure sustainable relationship among resource providers and consumers
e) Migrate to any members' device by moving a part of their code

Inside a grid or cloud community the need for reinforcing a collective intelligence model may be prove to be significantly profitable for all the participant groups. This is the case when the individuals' contribution to the grid or cloud is equal. However, a division of labour model can be applied to these communities as each member may have a different domain of specialisation. In other words, limitations of one member may be satisfied from any other member. Since not everybody can perform all tasks, a group where different individuals contain different knowledge will collectively cover a much larger domain.

VI. Case study: An Inter-Cooperated Crowd-y Cloud

By crowd-y cloud we define a community aware cloud in which users' perceptions and desires are captured from artificially intelligent agents. The crowd contains all kinds of devices that can access the grid or cloud and can utilize resources for any purpose [21]. In our view the intelligent agent model can serve the aforementioned vision as a means of achieving decentralization of grid and cloud VOs.

The Foundation for Intelligent Physical Agents (FIPA) provides a framework for an interoperable agent solution that can be used for the development of co-operating agent systems [19]. The agent service of the above standard provides an environment for organising the procedure of an agent travelling within unknown large scale domains with dynamic behaviour. We have proposed an approach that separates each mobile grid service into static and mobile parts that can dynamically migrate across grid nodes is presented in [11]. The specific design based on the FIPA agent management specification is the following:

a) Agent Management System as the place to create the agent life-cycle
b) Directory facilitator as a yellow page directory of the well known and trusted members addresses
c) Agent Container Service which provides the run-time environment of agents
d) Message Transport System which constitutes the communication bus among the agent platforms

In a previous work [2] we have discussed the resource discovery methods of interoperable grid agents based on the above FIPA specification. We analyzed existing resource discovery methods of agents and proposed a new solution for inter-collaborated agents [1]. In this paper we suggested that resource discovery is a systematic and continually updating process occurring directly within a VO. Finally, we concluded that solution of discovery includes either internal broadcasting agents, or internal travelling agents as a decomposition model of local agents in order to achieve an efficient and effective low response time.

In the following section we describe commercial efforts of the crowd-y clouds. In this way, we aim to utilize the intelligent agents' paradigm for delivering high quality applications, which implement major parts and concepts of grid and clouds. It is essential that we use specific middleware based on the Java Agent Development Framework (JADE) and that it is installed on all cloud devices [12]. In our case study, the grid technology serves a cloud by providing the problem solving environment, and the cloud provides the personalised view of the problem description. Notably, the underlying infrastructure maintains standard policies and securities articulated from the VO. In previous works we have defined the minimum requirements that need to be addressed and supported by grid members [1], [3]. We have organised the profile information to include Policy Management Control for identifying the level of agreed protocols for communication between different parties and addresses of trusted members. Then Knowledge Base Pairing is used as the procedure for job description coupling and the Physical Resources Announcement provides the mechanism for advertising internal hardware and software capabilities. Finally, Time Constraints for storing historical data about execution and communication times from previous delegations are also utilised. It is vital to acknowledge policies among different VO parties as well as respecting internal VO rules and actions.

In our study we aim to improve the Knowledge Base Pairing for collaborating members of a crowd-y cloud. More specifically, the agents travel through the cloud and by collecting information from each member's public profile, return back to their starting point. This position may be a stakeholder, and may be either the resource provider or the resource consumer. Our Example (Figure 2) we demonstrate the cloud of members, including providers and consumers. It should be mentioned that we decompose the cloud into smaller neighbourhoods that act as VOs. In addition the SCF offers a novel resource discovery method by acting a mediator in communication between the loosely coupled members.

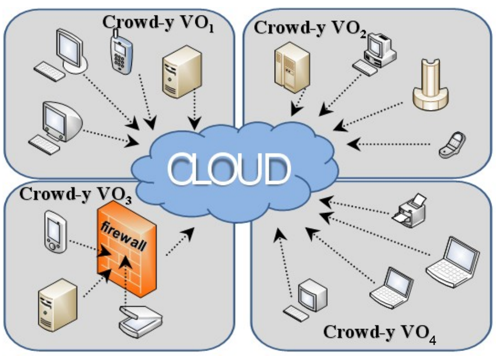

Figure 2: The crowd-y cloud of users

Each resource of the aforementioned figure contains the agent middleware for creating and destroying agents. Our example (Figure 3) consists of three members that are able to communicate with each other. A node is selected to be the host, which in our case will be able to create the agent service. The remaining nodes are capable of creating a sub-platform specification which refers to the Host member platform. The platforms consist of containers which could be scattered among many different hosts with one main container on a host running the Remote Method Invocation (RMI) service. All the agents on one platform communicate using the RMI protocol which is the intra communication mechanism internal to a platform. In other words, sub-platforms accept communication from an agent ***A***, while an internal agent waits for the connection. The agent starts from the host platform and by traversing a route to each node collects and updates the internal information and then returns back to the host.

The service can be repeated with any of the other members, however each time other parties should be alerted of the service creator address. On the other hand, inter-platform agents offer a decentralized model which creates platforms dynamically for each individual without having to know the other members platform settings. In such environments each VO member contains a different platform which is created locally and generates an agent. Agent functionality involves waiting for requests from other agent platforms in order to exchange internal knowledge. In other words, any of the agents are capable of performing communication directly so a new service can be created dynamically. Figure 3 illustrates this procedure.

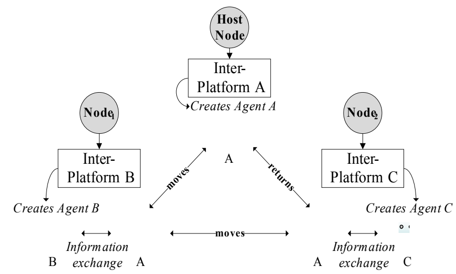

Figure 3: The inter-platform agent communication

The case discussed above illustrates the inter-platform communication model; in which agents are dynamically created by the inter-platform utility. The mobile agent migrates to a different platform and exchanges information with local agents. This solution predisposes the need for compatibility between different platforms and security issues are resolved by the agents. The economic gains of such an application to resource stakeholders are huge if we consider that these resource clouds may be transparent to the user and reliable to the provider. The virtualisation of the computational power, in conjunction with the heterogeneous nature of the grid, creates a scalable and elastic environment. Overall, the crowd-y cloud may address similar issues within any cloud system, but more importantly, we aim for a collective intelligence model of agents rather than a cloud of members.

The major benefits of a crowd-y cloud can be described from two perspectives; the resource consumer and the resource owner. We assume that each member contains a sensor API which may receive users' perceptions. These perceptions include noise levels, allergies, diseases and air pollution from the device holder environment, for example. The collected data may be transferred from member to member instantly as a form of resource information and may suggest, to users, statistics about low, medium, good and high quality for a particular locations or set of locations. By getting evidence from the environment as well as utilizing the grid functionality we may improve disaster relief, and in general generate environmental reports about

ISBN: 978-1-61208-101-4

specific geographical locations. Furthermore, policy makers may categorise the leasing opportunities for buying or selling properties according to noise levels. Also, governments may generate reports and warnings for health issues and welfare levels. In other words, future trends and technological possibilities are derived from the collaboration of technologies such as cloud, grid and virtualization, aiming to deliver a personalised product to users. By organising this collective intelligence we aim to propose that a larger collection of members are smarter than an elite few at solving problems, fostering innovation, coming to wise decisions, and predicting the future. The knowledge which is distributed everywhere can always be promoted, cultivated and improved. This could lead to an effective mobilization of skills. These skills are collected from an agent and stored within the metadata snapshot profile of a member.

VII. Conclusion And Future Work

In our study we have discussed a sufficient collaboration opportunity among grid and cloud computing, aiming to provide a collective intelligence model. The grid consists of VO members utilizing resources in order to solve VO defined problems but clouds are about users utilizing these resources to solve problems and proposing solutions. The future trend of these technologies is “reducing the carbon footprint” [18] so it makes them friendlier to the environment, and is also known as Green IT. We may consolidate numerous users in this direction by presenting the crowd-y cloud idea as an inter-collaboration environment with extensive capabilities. The market players should be ready for this step forward in order to improve their business by overcoming the obstacle of user requirements complexity. In this direction the agents based model may assist the resource provisioning model in a very proficient manner.

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