Towards decentralized grid agent models for continuous resource discovery of interoperable grid Virtual Organisations

Stelios Sotiriadis, Nik Bessis
Department of Computer Science and Technology
University of Bedfordshire, UK
stelios.sotiriadis@beds.ac.uk, nik.bessis@beds.ac.uk

Ye Huang
Department of Informatics
University of Fribourg, Switzerland
ye.huang@unifr.ch

Paul Sant, Carsten Maple
Department of Computer Science and Technology
University of Bedfordshire, UK
paul.sant@beds.ac.uk, carsten.maple@beds.ac.uk

Abstract— **Grid technology enables resource sharing among a massive number of dynamic and geographically distributed resources. The significance of such environments is based on the aptitude of grid members to look across multiple grids for resource discovery and allocation. Parallel to grid, agents are autonomous problem solvers capable of self-directed actions in flexible environments. As grid systems require self-sufficiency, agents may be the means by which to achieve a robust autonomy infrastructure. In this direction we propose a resource discovery method of interoperable grid agents which travel within Virtual Organizations (VOs) and by capturing resource information regarding their action domain; they update the internal data of each grid member. Moreover we propose that resource discovery is a systematic and continually updating process that occurs within a VO and allows information exchange to happen. This exchange takes place between various community members at a pre-defined interval, aiming to distribute internal knowledge about the domain.**

Keywords-component; Grid; Mobile Agents; Self-led Critical Friends

I. INTRODUCTION

Grid is an emerging computing infrastructure aimed at scalable environments within the context of VOs collaboration. In these environments the management of the huge number of resources is a critical and complicated element of the design of a grid community in which there is mutli-way participation. By considering the need for dynamic ability of VO members, we suggest that an autonomous solution of individuals may be a step forward to an open grid infrastructure. The mean to achieve self-sufficiency is the mobile agents' paradigm; with the ability to act in response to a member's requirements whilst also learning from their operational environment. The correlation between grids and agents have been discussed by several authors [9, 10, 11, 12], and all suggesting that both develop concepts and mechanisms for open distributed systems. In addition, by considering the grid as solving problems in dynamic and uncertain distributed environments [6], agents may be able to discover resources by acting flexibly. The sense of aforementioned standard is achieved through an inter-discovery notion of Self Led Critical Friends (SCFs), which provides an interoperable resource discovery concept on different grid VOs. More specifically, SCFs are community members of specific VOs that communicate between each other in order to extend their internal boundaries. Given this background it is essential to discuss the motivation of the research study and the challenges posed by previous authors (section 2 and 3). Then we discuss how the resource discovery phases may assist in the consolidation of a cooperating agent specification (section 4, 5). Finally we propose three solutions to the problems of interoperable grid agents (section 6). Different types of mobile agents are categorized into:

- Broadcasting agents which transmit information to any interacted member.
- Internal travelling agents which perform migration to any interacted member.
- Decomposition agents of smaller parts of VOs capable of performing broadcasting or migration of internal information.

More specifically, broadcasting agents achieve connectivity and transmit data to all individuals within a VO in a manner similar to broadcasting networks. On the other hand internal travelling agents pass through any connected member and visit each node once. Through the journey they update and collect information. Finally the decomposition of agents is a way of decomposing VOs in small parts. The best paths for resource discovery may be decided by using a heuristic algorithm.

II. MOTIVATION

An open grid predisposes the existence of several members of a huge collection of VOs which are interconnected (thereby forming the grid). The concept of *Self Led Critical Friends* (SCF) introduced in [4] defines a novel model as the next step to achieving collaboration between several VOs. Originally, the SCF act as intermediate stations in the communication between multiple grids by composing an extended environment. In our view the autonomous solutions may be presented in the course of the resource discovery process, detached from the resource selection and scheduling phase. More specifically, the resource discovery is defined directly by a VO member at periodic intervals in order to reduce the total communication time of the decision in the resource scheduling phase. It is the manner in which resources identify several components of the grid and the awareness of internal members' knowledge that is important here. In this direction, we suggest a systematic capturing and updating process within the boundaries of a VO. Herein, we propose a resource discovery model based on the minimum requirements that need to be addressed in order to achieve communication with interconnected members [1]. We aim to achieve the discovery by respecting policies of VOs, pairing job descriptions and finally by extracting information from members internal knowledge.

The information of each VO member is reflected in a profile called *Metadata Snapshot Profile* [4]. Essentially, the profile will be advertised to all VO individuals during the course of the resource discovery. At this stage we assume that the recorded information is extracted from a member's internal dataset; which includes the addresses of well known and trusted members, as well as the addresses of the SCFs. To capture such information, agents have explicit constructs for modelling internal roles. In more detail, agents are autonomous identifiable problem solvers, embedded in a particular environment and designed to exhibit behaviour of fulfilling a specific role. In our case the proactive scope involves the social interaction of members related to inter-cooperation aptitude.

III. Related Works

The dynamic availability and the heterogeneous nature of grid make resource discovery a challenging issue. A number of authors have describe the applicability of autonomic agents in grid environments [9,10] by suggesting that the grid needs agents as they form key components for a successful interoperable infrastructure. More specifically, authors in [11] suggest that software agents are programs that act on behalf of people and can accomplish a task by acting independently of the supervision of the user. By providing the ability to transport themselves between different systems, they can carry internal information which was obtained by each visited member. Finally their proactive and reactive nature makes them an ideal choice for a large distributed environment [12]. In the case of resource discovery, [5] proposes that there are various approaches for achieving discovery in grid environments such as the Query based and the Agent based approach. The Query based approach which is the most commonly used [13] allows the resource information to be queried for availability. Conversely, in the Agent based approach agents can passively monitor and distribute information periodically or in response to another agent. The major difference between the aforementioned methods is that an Agent is acting on its own decisions by using their internal logic in conjunction with the Query based approach which resides within a fixed query engine. Related works have utilized the agent framework to achieve the resource discovery of interoperable nodes. In [14] a web service agent has been proposed to simplify an interoperable model in which legacy web service components may have access to the agent system, thus encouraging interoperation. On the other hand [15] suggests that resource discovery is driven by autonomous multi-agents of the semantic grid and a standard interoperable web service has been addressed to some degree. Finally, the authors of [5] propose a grid service mobility integration of agents that enables the combination of the characteristics and the functionality provided by the agent paradigm, with the standardization provided for grid services. In the same direction the authors of [17] suggest that current agent based systems are immature and few truly agent-based systems have been developed, e.g. the Foundation for Intelligent Agents Framework (FIPA). The aforementioned enterprise standard represents a consortium for developing and sharing knowledge among several members. FIPA [16] provides a standardization agent model for an interoperable agent solution that can be used for the development of interoperable agent systems. The agent service referred standard; offers an environment for organising the procedure of an agent traversing within unknown large scale domains with dynamical behaviour. In this study we base our design on this standard and by defining an inter-agent model we propose a novel resource discovery strategy for interoperable VOs based on the metadata snapshot profile information. We have organised the profile information in [1] as follows:

- Policy Management Control for identifying the level of agreed protocols for communication between different parties and addresses of trusted members
- Knowledge Base Pairing as the procedure of job description coupling
- Physical Resources Announcement as the mechanism for advertising internal hardware and software capabilities
- Time Constraints for storing historical data about execution and communication times from previous delegations

It is vital to acknowledge policies among different VO parties as also respecting internal VO rules and actions.

IV. The Agent Resource Discovery Model

In a decentralized environment of grids many interconnected VOs collaborate with each other by utilizing the inter-connections between SCFs. In our work we propose that each VO contains one or more agents capable of traversing several routes within the VO, and finally by collecting and updating information discover resources dynamically. The agent functionality is used to assist, either continually or periodically, the resource discovery process. This process proceeds by travelling through a domain, starting from a random node, and after visiting each member terminates at the same node. Moreover, each VO agent may be cooperating with other agents within various VOs by utilizing the SCFs behaviour. An agent based resource discovery environment needs to search proffered resources quickly and efficiently and to return the correct results rapidly by reducing or even ignoring the network complexity. So the problems raised in such environments are how feasible it is to achieve cooperation of SCFs agents within an efficient amount of time. Moreover, a significant problem is that the updating process of the internal nodes snapshot profile needs to be effective with respect to the minimum value of interval time, when considering the whole resource discovery procedure within a VO.

The resource discovery of inter-connected members may occur in the following phases:

- The initialization phase, in which discovery starts from a randomly chosen member.
- The collecting and updating process, in which each member is kept informed of any new data about the domain.

More specifically the resource discovery starts from a node which requests information from the metadata snapshot profile of any connected member. The profile contains various types of data but we are seeking the addresses of well known nodes. In such situations we have to decide if the update procedure will be invoked at the time of job scheduling or periodically from all members at a randomly chosen time. In the case of job scheduling the total time may be enormous if the number of visiting nodes for resource discovery is large. Consequently, we propose a solution of periodically updating the metadata snapshot profile of a VO member by utilizing travelling agents. In this direction we clarify three different aspects of agents; a broadcast based information exchange procedure between pairs of nodes; a travelling agent model of updating node data; and finally a decomposition model of internal agents. In all cases the desired goal is to minimize the total communication time with respect to the interval time, as well as to provide quality of services updating among nodes.

V. Agent Service Specification

The agent service is capable of organizing the movements of agents and offers the platform for agents' generation and communication. The method is considered under the Foundation for Intelligent Physical Agents (FIPA) framework [16] which promotes multi agent based interoperable environments. The specific infrastructure consists of various entities such as the Autonomous Agent, the Metadata Snapshot Profile, the Agent Daemon Service and the Message Transport System. Figure 1 demonstrates the interaction among the agent service specification layers. The autonomous agent is an instance of the agent daemon, which is the container of the service. Each agent daemon is capable of creating a life-cycle for a specific agent which in turn is released from the service and can travel around a VO.

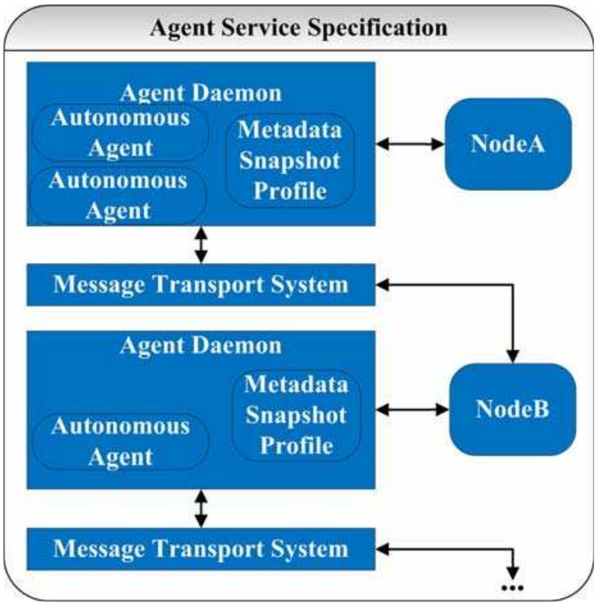

Figure 1. The agent service specification

The metadata snapshot profile is conceptually a *directory facilitator* [16] identical to a yellow pages directory of agent addresses. In this service members publish their internal knowledge which could be captured by the autonomous agents. It is essential that resource discovery occurs when an agent is generated by the daemon and when collecting and updating the metadata snapshot profile. Finally, the message transport system constitutes the communication bus [5] of the environment and is achieved by using Agent Communication Language (ACL) messages. A FIPA ACL message contains a set of parameters; which parameters are needed for effective agent communication will vary according to the resource discovery situation. The mandatory parameter in all ACL messages is the *performative* notion [16] which denotes the form of communication used for the ACL message. However it is essential that ACL messages contain sender and receiver addresses as well as content parameters. ACL messages are delivered through the message transport system bus between the agent daemon, the autonomous agent and the metadata snapshot profile. In any solution of inter-cooperated agents we assume that the above framework of communication is utilized at any point during the agent resource discovery process.

VI. Interoperable Multi-Agents

In the following sections we propose three different theoretical solutions of resource discovery agents. First, we discuss the internal broadcasting agents' method which transmits information directly to any interconnected node. After that we introduce the internal travelling agents which travel around within a VO. Finally, we conclude with a decomposition model of local agents in order to achieve an efficient and effective interval time solution. In the following solutions of interoperable grid agents we assume that the agent daemon is the container of the agent service which is responsible for generating autonomous agents. Moreover, the daemon is initially stored at a randomly chosen VO member, and then generates agent containers for any members with which it has an interaction. Finally, an agent is released from a VO node container and invokes each visiting node daemon. The procedure is finalized when the agent collects and updates the metadata snapshot profile of the member. Communication is achieved by utilizing the message transport system according to the FIPA specification [16].

A. Internal Broadcasting Agents

The Internal Broadcasting Agents utilise internal connections and transmit data to all individuals within a VO in a manner similar to that of broadcasting computer networks. The agent will (conceptually) be received by all nodes and is capable of collecting and updating the metadata snapshot profile of interacting members. In Figure 2 we assume that two agents exist in both VOs. They travel directly within a VO from a specific node to any other internal member by exchanging their metadata snapshot profile. In this case, an agent leaves $node_1$ at a specific time and collects information from each node of VO_1, including the information of $node_{10}$ about the members of the VO_2. On the other hand, an agent travels in VO_2 at a random time and collects and updates information of any internal node. In general, the interoperable concept achieved when agent 1 of VO_1 visits $node_{10}$ and requests data relating to $node_{20}$; so the new information concerning VO_2 is stored and returned to $Node_1$.

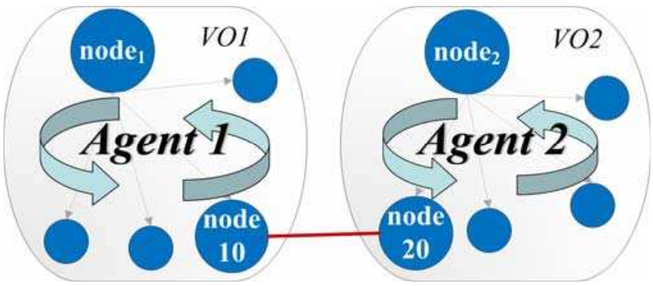

Figure 2. The Internal Broadcasting Agents communication

In this solution the interval time of the route for a VO is the sum of times for visiting each node. The main problems here is that the agent of VO_1 may not be capable of catching the new updated data of $node_{20}$ at the time of visiting it, as the interval time will be computationally infeasible if the number of visiting nodes is large. In this direction we propose the following solutions:

First: The agent must travel within a VO continuously, in order to collect and update the data; so we need to define the interval time of the specific pair-wise route and minimize it using an optimization technique.

Second: We need to store additional information at SCFs nodes about interval times. More specifically the agent of VO_2 stores data within $node_{20}$'s public profile including an average time of visiting this node again and also the last time this node was visited. In this case, the agent of VO_1 is capable of deciding the best solution, either waiting for new data or returning back to the $node_1$ with current information. Figure 3 describes the resource discovery phase for both scenarios.

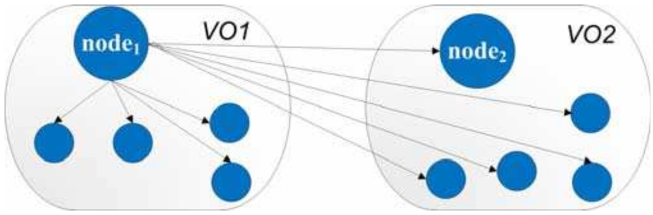

Figure 3. Resource discovery phase

Once this stage is complete we need to optimize directed paths between pairs of nodes for the resource selection stage. In this case we use a solution described in [2] that utilizes genetic algorithms for the purpose of finding the minimum weight of an optimized and weighted graph. In a typical VO each node agent travels within a domain and updates the personal profile of each node with which it shares an interaction. In this scenario it is evident that the communication time, even when minimize it, will be computationally infeasible as each member needs to broadcast and retrieve data from nodes within the VO.

B. Internal Travelling Agents

In contrast with the aforementioned broadcasting agents, internal travelling agents pass through any connected member and visit each node once. During this journey they update and collect information. Consequently, after a successful route we may have successfully updated the internal information as by utilising inter-cooperation between different VOs. We assume that an agent visits and collects information from each nodes public profile. The agent continues the journey within the domain to any interacting node and finally returns to the starting point. Figure 4 demonstrates the internal route of agents at two typical VOs.

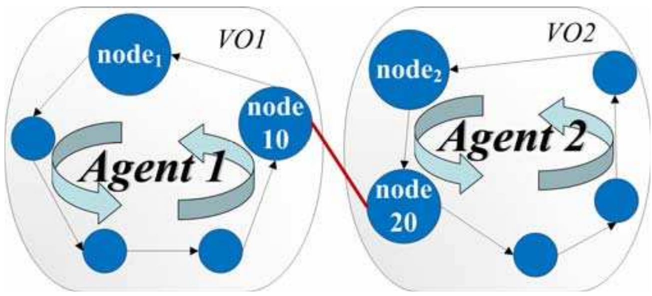

Figure 4. The internal Travelling Agents communication

In this situation agent 1 travels within VO_1 and collects and updates the public profile of each node. In this case an agent leaves $node_1$ and travels within VO_1, based on the addresses extracted from the $node_1$ metadata snapshot profile. The agent visits each node only once within a route and the procedure is invoked at a random point in time. Finally, the agent returns back to $node_1$ and updates the information of the member as well as that of any previously visited node. In this case we may face the following problems:

First: The interval time of a route may be infeasible because of the large number of nodes that need to be visited.

Second: The SCFs information may be outdated and we may lose information concerning newly added members.

One solution may be to consider that procedure is invoked at regular intervals; howbeit this denotes that all VOs should be synchronized in specific times. By considering the heterogeneous and unstable nature of grids, we may suggest that this is very difficult to take place in such environments. Another possible solution is to define each VO as a Self organizing map (SOM) and decide the best route according to information stored at a node after a successful traversal of a route. Notionally, the agent will be able to visit all nodes with lower communication cost as each node is only visited once. In the case of a typical VO we may consider that it is rare to add new members; so we may come up with a stable specific route within the boundaries of a VO. We may then define an average value for the interval time. In this way, we can decide (in a manner similar to the broadcasting solution) that an agent who arrives at a SCF will be able to decide whether to wait for new data based on the SCF information. However, in this solution we may have the following situations:

First: A new member has been added to the VO. In this case, the agent will behave in a similar way to existing members' by simply calculating a new route once the traversal has been successfully completed. In other words, the agent visits the new member at the first time of acknowledgment and after returning back to the starting point will be able to calculate a new route according to the SOM solution.

Second: The interval time of routes may be large even if the time has been reduced by the SOM. In this case we may consider a number of travelling agents according to the VO.

C. *Decomposition of Local Agents*

When adopting an agent-oriented view of the world, it soon becomes apparent that most problems require or involve multiple agents [9]. We therefore propose a method of decomposing VOs in practical small parts.

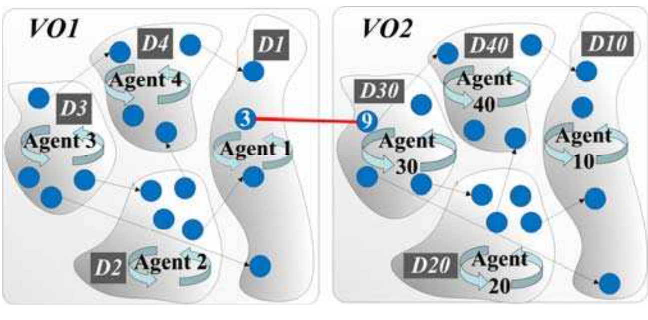

Figure 5. Decomposition of the local agents

The decomposed part of an interval time may be significantly lower than the total amount of the interval. So, by assigning roles to specific agents they can act as mediators in the communication among the decomposed parts. Considering a large scale VO with a large number of members, the total time of updating each internal snapshot profile will be a limitation to the open grid infrastructure. Furthermore the decision for selection and scheduling jobs will be affected by this constraint. In this direction, we propose the division of the VO in the case of internal agents so each part will perform communication and delegate jobs to any connected node, while several agents are able to travel through the domain and exchange information.

Figure 5 demonstrates the decomposition of agents which travel through the VO either by broadcasting or routing to each node separately

By minimizing interval times, we can provide a more reliable, fast, and autonomous clarification of interaction amongst small groups of members. The procedure is a straightforward model either we select a) broadcasting, or b) travelling agents.

As an example of our approach we assume that VO_1 contains four agents which travel within a decomposed domain of four small groups and they collect and update the information held about specified nodes. While the agent is visiting a specific node it updates the data of an interacting agent from another decomposed domain. In our example an agent of domain D_1 visits a node and collects and updates its information, and at the same time communicates with and agent in D_3 either by waiting for directed communication or just by harvesting information from a node. The same procedure is used when it visits any node; the agent again communicates with the agent of D_2 and exchanges information. The SCFs aspect of communication is based on $node_3$ of D_1 and each decomposed domain agent of VO_1 can access and collect data from any member of D_1. In this situation we may aim to reduce the total amount time required to update information by reducing the VOs into subsets of domain agents (each of which contain a small number of agents). However we may have the following problems:

First: A member fails to achieve communication.

In this solution we suggest that each particular member of a decomposed domain may be able to access resources of other domains, so if a member fails the other nodes will be able to detect new information from the agents of other domains.

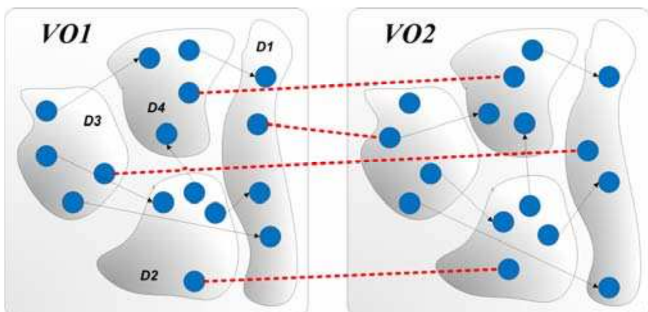

Figure 6. Communication among decomposed parts

In the aforementioned example, if $node_1$ fails, the $node_4$ can collect information from D_4 while D_4 agent collects information from D_3. So we may achieve the updated procedure without having any loss on information.

Second: A SCF agent fails and we may lose communication with an inter-connected VO agent.

If we consider Figure 5, it is apparent that inter-connection among VO_1 and VO_2 is based on members' $node_3$ and $node_9$, so this could lead us to a single point of failure. We assume that after a successful first interaction all members from both VOs contain the addresses of the interconnected nodes. In this situation, the problem of losing a connection with inter-agents may be solved by providing a communication line between each subset of decomposed domain agents and members of the other domain. Figure 6 demonstrates the procedure. In this solution we may employ either broadcasting or travelling agents to each pair of neighbouring domains and achieve significant reductions with respect to the interval times of members.

VII. CONCLUSION AND FUTURE WORK

In this paper we have proposed a theoretical approach of different decentralized agent models based on the SCFs' method. The three approaches may be utilized depending on the scale of VOs in order to achieve continuous resource discovery. The future work of the model includes the consideration of a new concept of mobility migrated agents, capable of performing migration between interacting VOs. The process can be extended by describing a stimulating model of migration agents and providing the functionality Autonomous agents, Agent Daemon's and Agent Metadata Snapshot Profile collection processes. Further work also includes the harvesting of physical resources and communication times by utilising the snapshot profile as well as a semantic representation of the metadata snapshot profile. To conclude, artificial intelligent agents offer an autonomous acting infrastructure of members with proactive and reactive aptitude. As grid is about sharing and allocation of resources within uncertain domains, intelligent agents may be the mean to achieve an autonomous learning environment of self-motivated members.

REFERENCES

[1] Sotiriadis, S., Bessis, N., Huang, Y., Sant, P., Maple, C., "Defining minimum requirements of inter-collaborated nodes by measuring the heaviness of node interactions". in: International Conference on Complex, Intelligent and Software Intensive Systems (CISIS 2010), IEEE, Krakow, Poland, February 2010.

[2] Sotiriadis, S., Bessis, N., Sant, P., Maple, C., "Encoding minimum requirements of ad hoc inter-connected grid virtual organisations using a genetic algorithm infrastructure". in: IADIS multi confernce on computer science and information Systems (MCCSIS 2010), Freiburg, Germany, July 2010. {To appear}

[3] Huang, Y., Bessis, N., Brocco, A.., Sotiriadis, S., Courant, M., Kuonen, P., Hisbrunner, B., "Towards an integrated vision across inter-cooperative grid virtual organizations". in: Future Generation Information Technology (FGIT 2009), pp.120-128, Springer LNCS, Jeju island, Korea, 2009.

[4] Huang, Y., Bessis, N., Kuonen, P., Brocco, A., Courant, M., Hirsbrunner, B., "Using Metadata Snapshots for Extending Ant-based Resource Discovery Functionality in Inter-cooperative grid Communities". In: International Conference on Evolving Internet (INTERNET 2009), IEEE, Cannes/La Bocca, France, August 2009.

[5] Athanaileas, T. E., Tselikas, N. D., Tsoulos, G. V., Kaklamani, D. I., "An agent-based framework for integrating mobility into grid services", Proceedings of the 1st international conference on MOBILe Wireless MiddleWARE, Operating Systems, and Applications, Innsburck, Austria, 2008

[6] Foster, I., Kesselman, C., Tuecke, S., "The Anatomy of the Grid: Enabling Scalable Virtual Organizations", International Journal of High Performance Computing Applications 15(3) (2001)

[7] Foster, I. and Kesselman, C., "The globus project: A status Report", in: Seventh Heterogeneous Computing Workshop, pp. 4, March 1998

[8] Iosup, A., Epema, H. J. D., Tannnebaum, T., Farrellee, M., Linvy, M., "Inter-Operating Grids through MatchMaking", in: 2007 ACM/IEEE SC07 Conference, pp. 1-12, November 2007

[9] Foster, I., Jennings, N. R. and Kesselman, C. (2004) Brain meets brawn: why Grid and agents need each other. In: 3rd International Conference on Autonomous Agents and Multi-Agent Systems, 2004, New York, USA. pp. 8-15

[10] Cox, P. D., Al-Nashif, Y., Hariri, S., "Application of Autonomic Agents for Global Information Grid Management and Security", in: Summer Computer Simulation Conference 2007 (SCSC 2007), San Diego, USA, 2007

[11] Zerfiridis, K.G. and Karatza, H.D., "Mobile Agents as a Middleware for Data Dissemination". Neural, Parallel & Scientific Computations, Dynamic Publishers, Atlanta, 2002, Vol. 10 (3), pp. 313-323.

[12] Zerfiridis, K.G. and Karatza, H.D., "Brute Force Web Search for Wireless Devices Using Mobile Agents", in: Journal of Systems and Software, Elsevier, 69(1-2) pp. 195-206, 2004.

[13] Sharma, A. and Bawa, S., " Comparative Analysis of Resource Discovery Approaches in Grid Computing", in: Journal of Computers, Vol 3(5), pp. 60-64, 2008.

[14] Zehreddine, W. and Mahmoud, Q. H., "An agent based approach to composite mobile web services", 19th International Conference on Advanced Information Networking and Applications, 2005. AINA 2005, vol 2, 28-30 March 2005, pp. 189-192

[15] Bellavista, P., Corradi, A., Monti, S., "Integrating Web Services and mobile agent systems.",25th IEEE International Conference on Distributed Computing Systems Workshops, 2005, 6-10 June 2005, pp. 283-290

[16] The Foundation for Intelligent Physical Agents (FIPA), http://www.fipa.org

[17] Bellifemine, F., Caire, G., Poggi, A., Rimassa, G., "JADE: A software framework for developing multi-agent applications", Lecture Notes in Computer Science, Intelligent Agents VII Agent Theories Architectures and Languages, pp. 42-47. Springer Berlin / Heidelberg (2001)