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GRID COMPUTING FOR COLLABORATIVE NETWORKS: A LITERATURE REVIEW

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Abstract

This paper describes the methodology and results of a literature review targeting the distinct interpretations of the Grid Computing paradigm within the context of Collaborative Networks. The review is based on the analysis of contributions published in selected scientific journals between 2002 and today. The analysis was performed taking into account the assumptions, scopes and solutions provided to approach the challenges for SMEs' collaborative networks. The research questions driving this literature review have been the following: (1) How is the concept of Grid Computing associated with the concept of Collaborative Network? (2) How the Grid computing supports Collaborative Networks? (3) What are the business implications in Grid supported Collaborative Networks?

Keywords: Collaborative Network, Grid Computing, Virtual Organization.

1 INTRODUCTION

Due to global pressure modern business markets are becoming more competitive. Many Small and Medium Enterprises (SMEs) are implementing changes in the way they conduct businesses in order to sustain their competitive advantages.

Central in this change is the notion of "network" in which SMEs and professionals seek complementarities and joint activities allowing them to participate in competitive business opportunities or in new markets. Many different conceptualizations of "network" have been described in literature (e.g. industrial district [1], extended enterprise [2], virtual enterprises [3, 4], virtual organization[5], community of practice [6], etc.). This paper focuses on Collaborative Networks (CN), defined by Camarinha-Matos et al. as "*networks constituted by a variety of entities that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital, and goals. Nevertheless these entities collaborate to better achieve common or compatible goals, and whose interactions are supported by computer networks*" [7].

Actually, to enact a "plug and do business" [8], different technologies have been adopted (e.g. EDI, SOA, Grid Computing, etc) and innovative solutions and enabling platforms, allowing the synchronization of business processes and the interoperability of information and operational systems have been developed. Information and Communication Technologies (ICT) have been used beyond purely operational and management support and ICT systems that cross organizational boundaries have been diffused. Such inter-organizational systems blur the structural boundaries of isolated organizations enabling an easy exchange of information from one to another.

Among the technologies supporting the full life cycle of collaborative networks the Grid Computing paradigm [9] evolved over time. Its early conceptualization appeared in the parallel computing literature and it was mostly oriented to address heavy computation as those characterizing scientific environments. Recently the concept of Grid computing has been extended to capture the specificities of several business domains and different flavour appeared [10].

This paper describes the methodology and results of a literature review targeting the distinct interpretations of the Grid Computing paradigm within the context of Collaborative Networks. The review is based on the analysis of contributions published in selected scientific journals between 2002 and today. The analysis was performed taking into account the assumptions, scopes and solutions provided to approach the challenges for SMEs' collaborative networks. The research questions driving the literature review have been the following: (1) How is the concept of Grid Computing associated with the concept of Collaborative Network? (2) How the Grid computing supports Collaborative Networks? (3) What are the business implications in Grid supported Collaborative Networks?

2 MATERIALS AND METHODS

An automated literature search was performed querying the Business Sources Premier (BSP) database, which contains references and full texts of articles from more than 12.000 scientific journals, mainly in the economics and social science domain. The search was then extended, in order to include the journals published by Blackwell (around 950), Elsevier (around 2100) and Springer (around 500). The search was performed in the abstract, using free text words combined together in an appropriate way. No time limits were assumed with respect to the publication date.

Initially the term "Grid" was ANDed with the ORing of the following terms: "collaborative network", "organization"," enterprise", "collaboration", "cooperation", "coordination", "business", "district". This first search yielded 388 papers. Nevertheless, due to the fact that in English the term "grid" is mainly used as a synonymous of "power grid", "matrix" or "net", a refinement in the research strategy was needed. With the aim to concentrate to the technological paradigm and eliminate the noise, in a second step the term "grid" was substituted with the ORing of the following terms: "grid computing", "data grid", "enterprise grid", "global grid", "services grid" and "knowledge grid".

As a further refinement on the results set, papers not written in English or not electronically retrievable in full texts were excluded.

3 RESULTS

In the literature review 105 papers were analyzed, 27 from BSP and 78 from the other journals considered (the complete list is available in [11]).
The papers retrieved were published between 2002 and June 2008 with a distribution per year shown in Figure 1. Note that the number of papers published in the first part of 2008 (17 before data collection) is not shown due to the fact that it is a partial value.

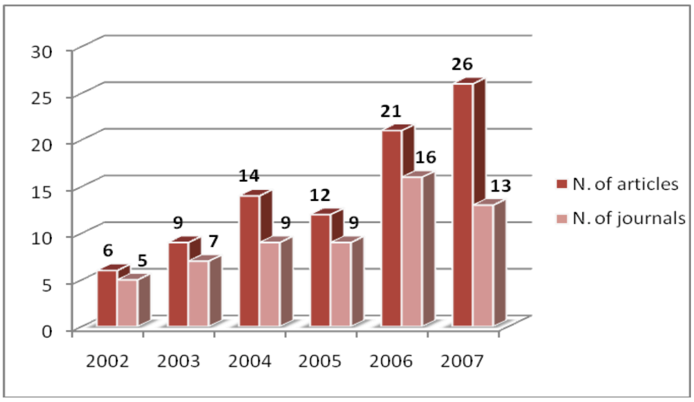

Figure 1: Distribution of papers per year

Paper were published in 53 different journals. Table 1 shows their distribution in different fields according to the taxonomy proposed by the publisher Elsevier.

Domain	Total of Articles	N. Articles per journal	Journals
Computer science	61	30	Future Generation Computer Systems
		7	Parallel Computing
		3	Communication of the ACM; Journal of Systems Architecture; Journal of Parallel and Distributed Computing
		2	Network Security; Web Semantics: Science, Services and Agents on the World Wide Web
		1	ACM Computing Surveys; Computational Intelligence; Computer Networks; International Journal of Parallel Programming; Journal of Computer Information Systems; Journal of Interconnection Networks; Parallel Processing Letters; Performance Evaluation; IEE Proceedings Software; International Journal of Image & Graphics; International Journal of High Performance Computing Applications
Engineering and Technology	21	5	IBM System Journal
		2	Applied Artificial Intelligence; Information Security Technical Report
		1	Computer Graphics Forum; Computer in Industry; Computer Standards & Interfaces; Engineering & Technology; Intel Technology Journal; The Journal of Systems & Software; IBM Journal of Research & Development; Technological Forecasting & Social Change; Engineering Applications of Artificial Intelligence; Journal of Computer and System Sciences; Knowledge-Based Systems; Microprocessors and Microsystems.
Physics and Astronomy	6	3	Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment;

		1	New Astronomy; Nuclear Physics B-Proceeding Supplements; Computer Physics Communications;
Health	5	2	Briefings in Bioinformatics
		1	Computerized Medical Imaging and Graphics; Journal of the American Medical Informatics Association; Journal of Biomedical Informatics
Business, Management and Accounting	3	1	Electronic Market; Human Systems Management; Telecommunication Policy
Decision Science	3	2	Expert Systems with Applications
		1	Information Science
Neuroscience	2	1	Neuroimage; International Congress Series
Social Science	2	1	The Internet and Higher Education; Computer & Education
Energy and Power	1	1	Reliability Engineering and System Safety
Environmental Science	1	1	Environmental Modelling and Software

Table 1:Distribution of papers per class of journals

More in details, the 28% of retrieved articles were published in a single journal, Future Generation Computer Systems, focused on all aspects of Grid and distributed computing. The remaining articles were published in 52 different journals covering Computer Science (58%), Engineering and Technology (20%), Physics and Astronomy (5%) and other scientific and social science domains.
The topics approached in these articles were examined by means of a content analysis technique. The results are discussed in the following subsections.

3.1 What is Grid?

The definition of Grid assumed in most of the papers considered corresponds or is explicitly related with one of those provided by Ian Foster (see Table 2).

1999	*A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities* [9].
2001	*Grid computing is concerned with "coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations* [12].
2002	*A Grid is a system that coordinates resources that are not subject to centralized control, using standard, open, general-purpose protocols and interfaces to deliver nontrivial qualities of service* [10].

Table 2: Definitions of Grid provided by Ian Foster

Nevertheless, due to the fact that the author's definition of Grid evolved over a time frame of four years, it is not unique. Actually in spite of this evolution, two different streams were identified: the former referable to the Foster's definition provided in 1999; the latter to the one provided in 2001.
In particular in the first stream the investigation on Grid Computing is mostly focused on computational aspects. In fact, in origin the research and development of Grid Computing technologies was mainly driven by the demand for a tremendous computing power within high performance computing communities [13]. In this context a Grid is often thought in terms of providing a distributed system of high-performance computing resources [14, 15], and a Computational Grid is*:*

- *a collections of networked computers that pool their resources together in such a way that users may utilize processing, storage, software, and data resources from any of the interconnected computers* [16]*;*
- a "metacomputing" environment, that allows applications to utilize multiple computational resources that may be distributed over a wide-area network [17];
- a federations of geographically distributed heterogeneous hardware and software resources [18-20] presenting the illusion of having a single virtual computer available for computing intensive application [21-24].

In the second stream the characteristics defining a Computational Grid are: (i) a resource sharing among a large amount of Grid users; and (ii) a support for collaborative computing services. According to Afzal et al. functionally*, "Grids are tools, middleware, and services for (i) providing a* *uniform look and feel to a wide variety of distributed computing and data resources; (ii) supporting construction, management, and use of widely distributed application systems; (iii) managing and securing this computing and data infrastructure as a persistent service, facilitating human collaboration and remote access to, and operation of, scientific and engineering instrumentation systems"* [25]. Grid computing is an approach for building dynamical problem-solving environments using geographically and organizationally dispersed high-performance computing and data-handling resources [22, 25-31]. These definitions caught Foster's intentions to wider the definition of Grid *in order to address social and policy issues* [9], hence Grid computing does not only enables the distributed collaboration among computers, but also (and mainly) the distributed collaboration among people behind the computer [33, 34]

3.2 Grid resources shared in a Collaborative Network

Different types of Grids are defined in literature depending on what kind of resources are shared within the collaborative network:

- *Computational Grids* are those where the focus is on the sharing of computational resources. In these middleware-oriented Grids the aim is to present the illusion that applications work together in a single system when in reality they do not.
- *Service Grids* (and/or *Application Grid*) are a specialization of Computational Grids which support specific business domains such as electronic commerce, telemedicine, distance learning, and Business-to-Business [25, 29, 35-38]. These applications typically require the support from a wide spectrum of end services such as: monitoring and tracking, remote control, maintenance and repair, online data analysis, and business support, as well as services involving a human decision such as legal, accounting, and financial services.
- *Access Grids* are powerful tools to improve communication among geographically distributed teams, playing a key mediating role in the communications between humans. An Access grid is a specialized facility that consists in a set of resources that includes interactive multimedia within high-speed networks, and group-to-group collaboration tools [33]. Grid access have extended traditional desktop video conferencing tools using the Internet and the multicast communication.[39].
- In *Data Grids* the emphasis is on the sharing of data. Data Grids present a single virtual data store that is in reality distributed and multi-located. In this perspective also the World Wide Web can be viewed as a data grid where numerous HTTP servers provide text, image, audio, and other forms of data resources and where portals provide a way for application developers and users to submit their compute job or their query [40-47].
- *Knowledge Grids* are platforms that enable the sharing and managing of distributed heterogeneous resources (including information, knowledge and services) spread across the Internet in a uniform way. It includes multi-dimensional resource spaces (such as knowledge space and information space) and resource operations that enable users to store and access the resources with different privileges including personal-privacy, group-privacy and public sharing [48-52]. In this context the *Semantic Grid* is a recent initiative to expose semantically rich contents associated with Grid resources to build more intelligent Grid services [53-55].

3.3 Grid and collaboration

An interesting element in the definition of Grid provided by Foster in [9] is the explicit reference to Virtual Organization (VO), a term frequently appearing in the social science literature, and identifying an ICT supported, dynamic and flexible model of interaction and collaboration among a group of people or organizations sharing a common goal [5].

In the Grid literature examined a VO is frequently defined as a collection of resources that need to be shared by application users [21, 56, 57] over particular periods of time [58], but also as a dynamic group of individuals, teams, or organizations [25, 30, 53, 59-67] who agrees the conditions and rules for sharing resources [35]. Laccetti et al in [68] says that a VO *"is created when people and resources from one or more real organizations are shared to tackle problems that require the combined efforts and resources of the VO members. As such, VOs are "containers" for collaborative problem-solving,* *and many usage scenarios actually consist in small working groups within a long-lived VO that need to establish augmented interoperability, either in a well-structured, persistent way (ad-hoc collaboration), or for only a short period of time and in a non-structured way (transient collaboration)"*. The last part of this definition is similar to the one provided in [7] in which VOs are considered *as a particular manifestation or variant of a Collaborative Network (CN).* In such a view CN are based on ICT facilities, centered on virtuality, and collaboration is an intentional property that derives from the shared belief that together the network members can achieve goals that would not be possible or would have a higher cost if attempted by them individually [7].

3.4 Business domain for Grid Computing technologies application

In literature an important distinction is made with respect to Grid solutions applied either to scientific or to business oriented collaborative networks.

Physics was the first area that used the Grid technology. Actually Grids originated with the development of systems that allowed the pooling of IT computing resources within a single organization in order to answer physicists demands, which were too large for any single facility [25]. In recent years Grids have been rapidly diffused in many other scientific domains (medicine, astronomy, etc) at the point that it favoured the development of the eScience [49, 69], a discipline that envisages using high-end computing, storage, networking, and Web technologies together to facilitate collaborative, data-intensive scientific research [10, 70]. In [22, 37, 45, 59, 61, 70-74] is argued that Grid Computing has moved beyond scientific disciplines into "softer" areas as the arts, business, and economics.

In the business domain, Grid Computing provides tools for the management of shared business processes, to enable the sharing of knowledge among entities, and a favourable environment for communication within teams [50]. Besides reducing the risk on IT investment, by enabling a more efficient use of existing computing infrastructure [45, 59] and allowing a flexible computing resource provision [59, 73], Grids are considered as general facilities for simplifying the management of distributed workflows. In an environment where business organizations and, more specifically, SME are dealing with the need to integrate their activities with other different companies along the value chain, Grid therefore, become a killer application, providing important contributions to enable more advanced models of collaboration in a inter-organizational dimension and fostering the definition of new business models [45, 61].

Based on differing levels of complexity, Grids in business oriented collaborative networks can be categorized as one of the following two types: (i) *Extra-grid* or *partner grid*, where sharing of resources is extended outside a single organization to include those belonging to a trusted external partner with whom a business relationship has already been established; (ii) *Inter-grid*, where computing and data/storage resources are shared across public Web in collaboration with other enterprises. In the former type mutual or shared partner agreements and service-level objectives on resource utilization are required, while in the latter there are inherent complexities in managing service-level requirements, security federation, and integration [35].

Nevertheless, according to [75] this technology still has a long way to go through before having its potentialities widely and deeply exploited in CNs. In fact, as emerged from the literature review, today Grids are generally developed and adopted within large corporations that have a global presence, remaining, therefore, in a intra-organizational dimension. The main system studied and developed in the business domain is the "Enterprise Grid" [68, 72, 74]. This system, also named "virtual private grid" [34] or "campus grid" [35] or "intra-grid"[16], are managed by a single organization, consists of resources spread across an enterprise, and provides services to the users within that enterprise.

4 DISCUSSION

As suggested by the positive trend in the number of articles per year and by the high number of journals where articles were published, the Grid computing paradigm could be considered as an emerging research domain gaining growing interests. Nevertheless, if in one hand the Grid paradigm

can represent, both conceptually and operationally, a strategic support for SME, on the other side many issues for collaborative business are still open.
Often in the business domain Grids are strictly perceived as a mean for deploying massive processing power in order to solve highly intensive computational problems, and firms do not believe that they can be of value in addressing their more modest computing requirements [37]. Also, in real business environments SME still encounter the issues of motivation, flexibility, compatibility, security, and workflow management during the implementation of a Grid [24].
Moreover, unlike the pure scientific research environment, many organizations are keen about their autonomy and their right on both their proprietary data and local resources [75]. Enterprises are unwilling to commit the execution of their competitive business processes or the storage of their precious data to a computing resource that is not under their immediate and complete control [37]. These resistances are related to the fear on computing errors, damages to the system or spy actions [34], but also to the legal hindrances in force in certain business domains (i.e. in healthcare), where regulated companies cannot export data for processing or storage purposes [37].
In order to deal with these issues different perspectives were adopted. Several contributions interpret the Grid computing as an evolving area where standards and technology are still being developed [73, 75]; they concentrate their efforts on the improvement of interoperability standards, resources management mechanisms [27, 35, 56, 76, 77], security policies [16, 18, 68, 71], and easy to use interfaces [73]. Nevertheless this technology driven approach risks to neglect the social and economical aspects of collaboration.
Other contributions (e. g. [19, 60, 78, 79]) focus on the application of market- or social-driven economic models for the definition of resource sharing mechanisms (such as auction model [79], Commodity market [78], marketplace-based economical model [19]). Nevertheless these works are mainly focused to the theoretical analysis of economic mechanism and fails to analyze specific economic issues from a business perspective.
A third perspective focuses on Grid technology adoption considering VO as one of the most important drives. VO are based on the automation of inter-organizational coordination and Grid technologies allows the organisations to efficiently share and utilise their geographically distributed computing, storage and data resources over a common infrastructure. Nevertheless the control requires a strong motivation towards cooperation which could be based on a common business culture [81], as well as on trust, reputation, loyalty, and more in general on the sharing of a common value systems. In this perspective, an ideal context for the Grid application is the industrial districts [81], defined as a group of "co-operating decisionally and financially independent small-medium sized enterprises, located into a specific social and cultural geographic area, highly specialized on one or more phases of a production process. These districts represent a business environment where trust and cooperation willingness constitutes the enabler of the highly parcelled value chain".
Nevertheless in a fully electronic environment these dimensions rarely established spontaneously and specific efforts are needed to put in place situations and conditions enabling the development of dynamic cooperation among enterprises (e.g. marketplace). In [80] this environment is defined as VO Breeding, i.e *"an association (also known as cluster) or pool of organizations and their related supporting institutions that have both the potential and the will to cooperate with each other through the establishment of a "base" long-term cooperation agreement and interoperable infrastructure. When a business opportunity is identified by one member (acting as a broker), a subset of these organizations can be selected and thus forming a VE/VO".*
As a result of the literature review the latter position, even if promising, is still largely unexplored and in the author's opinion it represents an interesting starting point for further investigations on the potentialities and limits of Grid computing in virtual district environments.

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