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Pervasive and Grid Computing Merging

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INTRODUCTION

Nowadays, we are experiencing an increasing use of *mobile and embedded devices*. These devices, aided by the emergence of new wireless technologies and software paradigms, among other technological conquests, are providing means to accomplish the vision of a new era in computer science. In this vision, the way we create and use computational systems changes drastically for a model where computers loose their "computer appearance." Their sizes were reduced, cables were substituted by wireless connections, and they are becoming part of everyday objects, such as clothes, automobiles, and domestic equipments.

Initially called *ubiquitous computing*, this paradigm of computation is also known as *pervasive computing* (Weiser, 1991). It is mainly characterized by the use of portable devices that interact with other portable devices and resources from wired networks to offer personalized services to the users. While leveraging *pervasive computing*, these portable devices also bring new challenges to the research in this area. The major problems arise from the limitations of the devices.

At the same time that *pervasive computing* was attaining space within the research community, the field of *grid computing* (Foster, Kesselman, & Tuecke, 2001) was also gaining visibility and growing in maturity and importance. More than just a low cost platform for high performance computing, *grid computing* emerges as a solution for virtualization and sharing of computational resources.

In the context of virtual organizations, both grid and *pervasive computing* assemble a number of features that are quite desirable for several scenarios within this field, notably the exchanging of information and computational resources among environments and organizations. The features of these technologies are enabling system designers to provide newer and enhanced kinds of services within different contexts, such as industry, marketing, commerce, education, businesses, and convenience. Furthermore, as time goes on, researchers have made attempts of extracting and incorporating the better of the two technologies, thus fostering the evolution of existing solutions and the development of new applications. On the one hand, *pervasive computing* researchers are essentially interested in using wired grids to hide the limitations of *mobile devices*. On the other hand, *grid computing* researchers are broadening the diversity of resources adhered to the grid by incorporating *mobile devices*.

This chapter presents part of our experiences in the research of both pervasive and *grid computing*. We start with an overview about grid and pervasive technologies. Following, there are described and discussed approaches for combining pervasive and *grid computing*. These approaches are presented from both perspectives of grid and *pervasive computing* research. Finally, in the last section, there are presented our criticisms about the approaches discussed and our hopes about the future steps for this blend of technologies.

GRID AND PERVASIVE COMPUTING

Grid computing (in short grids) was born as a low cost alternative for high performance computing, rapidly evolving to a solution for virtualization and sharing of resources. By spreading workload across a large number of computers, users take advantage of enormous computational resources that would otherwise be prohibitively expensive to attain with supercomputers. To day, grids try to leverage a world where the access to any computational resources across sites is standardized, ubiquitous and reliable.

Grids are characterized by the use of heterogeneous and non-dedicated resources, scattered under different administrative domains and linked through low-bandwidth channels. There are no guarantees neither whether a certain resource will be available at a certain moment nor, once available, it will keep available during any interval of time. Due to these features, grids are best suited for applications that can adapt themselves to deal with *intermittent resources*.

More recently, grids are going towards defining a *service-oriented architecture*, OGSA[1], where resources are advertised and used as services. OGSA extends traditional *service-oriented architectures* by the standardization of a number of helper services, concerned with the maintenance of the whole infrastructure. Such services include load balancing, QoS[2] assurance, redundancy of services, and so forth.

Pervasive computing is also a kind of distributed computing. The general vision is that computation is embedded in objects of everyday life, such as clothes, rooms, automobiles and domestic devices. These objects and environments collaborate on behalf of people, balancing proactivity, *context information* and pre-known information about users' profiles to provide personalized services to users, on the right place and on the right moment.

Pervasive computing materializes in the form of *smart spaces*. These environments are characterized by collaboration between embedded devices, wired infrastructure and users. Normally, users interact with *smart spaces* through portable devices. These devices carry information about the users' profiles and may tell the environment how the user wishes to interact with it. Alternatively, the environment itself may know about users' profiles, and query them by "sensing" users through sensors. Regardless of how the environment gets aware of users' profiles and how it senses the presence of users, the basic principle of *pervasive computing* is to disappear from human perception. In other words, users should benefit from decisions made by environments without being prompted every time about what they wish the environment does for them.

THE PERVASIVE PERSPECTIVE

Pervasive computing is mainly characterized by the use of resource constrained *mobile devices*. Thus, from the perspective of *pervasive computing*, the main research focus is on using resources of grids for supplying lacks of *mobile devices*.

Current approaches for bringing together grids and *pervasive computing* will be discussed in the following.

Using Grids for Hiding Limitations of Mobile Clients

In the perspective of *pervasive computing*, using grids for supplying the lack of resources of *mobile devices* seems to be the major contribution that grids may bring to the *pervasive computing* research. Grids have plenty supply of resources that are needed by mobile clients. Nevertheless, current attempts to virtualize the capacity of mobile clients (Clarke & Humphrey, 2002; Hingne, Joshi, Finin et al., 2003; Kumar & Song, 2005;) still falls into strong assumptions about the communication between mobile client and grid. Particularly, successful applications of this approach are yet restricted for those cases where the interaction between mobile client and grid requires low data exchange or where some alternative is found for supplying the system with needed data.

For instance, Kumar and Song (2005) proposed a grid-based infrastructure where mobile clients run only helper applications linked to the grid. As proof of concept, a virtual file system was developed linking some folders in the PDA's file system to a bigger hard disk in the grid. Thus, files and full programs may be moved to the grid, staying in the PDA only those files and programs more frequently used. All content moved to the grid is consumed on demand through streams.

The approach of Kumar and Song (2005) reveals the main weaknesses of integrating pervasive and *grid computing*. Due to limitations of battery autonomy, portable devices should avoid using intensively their network interfaces. Therefore, a successful integration between grid and *pervasive computing* should consider applications where there are not large amounts of data being exchanged between portable devices and grid.

The issues of restricted data exchange between portable devices and grid are better targeted by Hingne