The Proxy-Based Mobile Grid

Azade Khalaj, Hanan Lutfiyya, and Mark Perry

Computer Science Department
The University of Western Ontario, London ON N6A 3K7, Canada
{akhalaj,hanan,markp}@csd.uwo.ca

Abstract. The increase in the popularity of small digital mobile devices also implies an increased demand in applications. The limited computing capabilities on the mobile devices and the unreliability of wireless links are barriers to the smooth access of mobile devices to the Grid applications and resources. In this paper a proxy-based approach is presented that is able to support various kinds of applications to be used by mobile devices by providing specific-purpose services on the proxy. The implemented prototype that includes some of the realized proxy services and the example client application for a mobile device show the viability of the proposed approach.

Keywords: Mobile Grid, Grid Computing, Mobility, Proxy, Proxy-based Architecture.

1 Introduction

In recent years we have seen a proliferation of mobile consumer electronic devices e.g., smartphones, PDAs and tablet PC. With this proliferation there is an increased demand for the following: (i) The ability to run resource-intense applications such as video playing or editing. However, the devices have limited compute power due to size and weight constraints. This suggests a need to offload computation from mobile devices to servers with sufficient computational power; (ii) Access to peripheral devices such as printers; (iii) Access to remote services that rely on information from multiple sources. For example, urban planners are proposing to allow city residents to provide information in real-time about specific events e.g., car sensors may provide information about traffic patterns. In other words there is a desire to access through a mobile device a "hardware and software infrastructure that provides dependable, consistent, pervasive and inexpensive access to high-end computational capabilities and peripheral devices" [24]. We will refer to this infrastructure as the Mobile Grid.

The challenges in providing seamless and transparent access to the mobile grid include the following: (i) Most mobile devices have limited computing resources; (ii) Devices are mobile and often connect to the Grid through wireless connections which are not as reliable or have the same bandwidth as wired connections; (iii) Battery power is limited and this may cause frequent disconnection of mobile devices.

Y. Cai et al. (Eds.): Mobilware 2010, LNICST 48, pp. 59–69, 2010.

The literature shows two main approaches to creating and accessing a Mobile Grid infrastructure. In the first approach researchers extend the available tools and middleware [1,20,29,9] for the Grid computing. A software is installed on the mobile device. The software delegates tasks to components added to the Grid middleware on the wired part of the Grid. The second approach, using a proxy-based architecture, introduces a proxy component (several example of this approach are referenced in section 5). In this approach, the application on the mobile device delegates the task of communication with services on the Grid to a proxy machine which is assumed to be a highly capable node on the wired network. The components on the Grid see the proxy as a Grid component and applications on the mobile device interface with proxy and communicate with it as a bridge to the Grid. In this approach, the Grid middleware remains unchanged and the resource constrained mobile devices are not exposed to the complexity of the Grid, since dealing with these complexities is shifted to the proxy.

The limitation of the first approach is that it does not adequately address issues related to accessing peripheral devices or remote services since the Grid middleware typically focusses on executing submitted tasks. Using a proxy eliminates the need to alter the currently deployed Grid middleware. A proxy is more flexible and thus facilitates access to peripheral devices or remote services. The use of proxies is challenging in itself.

The goal of our work is to develop a middleware that facilitates the use of Grid resources for mobile devcies through a proxy. Grdi resources include application services or hardware. However, the development of a middleware requires that we identify the types of services that a proxy should provide. These services enable proxies to support different applications with different requirements.

These services can be implemented as independent services on the proxy that are to be called Proxy Services and are deployed on the proxy when a client application has a request to use it. When there is no client using a Proxy Service, the Proxy Service can be terminated on the proxy machine to free resources for other processes. In this way, dynamic proxies will be created that have a changing set of Proxy Services. Beside the identified possible Proxy Services, the process of finding a proxy (by a mobile device) and two application scenarios as usecases of our proxy-based Mobile Grid infrastructure are described in this paper.

The remainder of the paper is organised as follows. In section 2 two usecases are explained that in them applications on the mobile devices use our infrastructure to call some Grid services. Section 3 describes the role of proxy in our proposed Mobile Grid infrastructure. A simple prototype of our proposed infrastructure and an example application which is used to test the prototype are presented in section 4. Related research done in this area and the conclusion and future work are presented in sections 5 and 6 respectively.

2 Usecases

To understand the requirements needed to be provided by an infrastructure that uses proxies, two possible application scenarios are presented in this section.

These applications communicate different kinds of data with services and components on the Grid. The proxy machine is the actual client of services on the Grid, so the Grid should be available only on the proxy. It is enough to have a light-weight application on the mobile device to communicate to the proxy. The proxy can buffer the results received from Grid resources in the case of a disconnection between the mobile device and the wired network and deliver the result to the mobile devices whenever it reconnects to the wired network.

2.1 The e-Health Application Scenario

Imagine a situation where a paramedic is treating the patient at the scene of an accident or at the patient's home. The paramedic has an application on his/her handheld device that is able to use teh proxy provided in our Mobile Grid middleware as a client. We assume that the application has triggered the process of finding an appropriate proxy after being launched by the paramedic on the cell phone (the details of the process of finding a proxy are described in section 3.2). Upon completion of this process a proxy is assigned to the application that has the requested Proxy Services of the client application deployed on.

The paramedic gathers the needed information about the health status of the patient using the medical equipment available in the ambulance. If an "ECG Signal Aalyzer" service is needed the paramedics uses the client application on the handheld device to discover the ECG signal analyzer service on the Grid. The paramedic might need to talk to a consultant at the affiliated medical center through an audio/video connection. This connection can be established between the paramedic's cell phone and the medical help center. Since this connection passes through the proxy, a specific Proxy Service on the proxy can be used to control the QoS level for the audio/video stream based on the condition of the wireless link and the hardware specification of the device. If it is necessary the "Hospital Finder" service can be invoked by the client application in the same way as invoking the "ECG Signal Analyzer" and an appropriate hospital is selected taking into account several factors such as the distance, the traffic condition of route to the hospital and the availability of required facilities at the hospital.

Since all this communication passes through the proxy, the proxy can provide a Proxy Service which is responsible for handling disconnections. The Disconnection Handler Proxy Service is responsible for buffering messages sent by the Grid services, e.g. "the ECG Signal Analyzer", to the client application at the proxy in the case of a disconnection happening between the mobile device and the network. After the reconnection, the Disconnection Handler Proxy Service will send the buffered messages to the client application on the handheld device.

2.2 Finding the Closest Printer

A university provides its visitors with access to some of the campus printers by providing a "Printer Finder" service. The "Printer Finder" service is implemented to find an appropriate printer for the user. An appropriate printer is the one that the visitor has permission to use and is located in the proximity

of the user. A small client application for handheld devices is provided by the university that is designed to call the provided web service. Visitors are able to call the "Printer Finder" service at anytime and anywhere to find the closest accessible printer. The client application for the handheld device is designed to use our Mobile Grid infrastructure to call the "Printer Finder" service provided by the university. If a person visiting the campus needs to find a printer, he/she launchs the client application. The client application first starts the process of finding a proxy and after that it submits a request to the proxy that includes the address of requested service and its current GPS position. Consequently, the proxy contacts the proxy finder service and relay the request of mobile device to it. After receiving the result from the printer finder web service, the proxy sends back the result which includes information about the found printer to the client application. The client application is supported by the disconnection handler mechanism provided in our infrastructure. If during a call to the "Proxy Finder" service a disconnection appears, the Mobile Grid infrastructure is able to buffer the result for the client application and deliver the result after a reconnection to the client.

3 Our Proposed Approach

In our proxy-based Mobile Grid infrastructure proxies play the role of gateway for mobile nodes to the Grid. The proxy enables mobile devices to be part of the Grid as a resource provider or resource consumer by doing some tasks on behalf of the mobile device. A proxy is machine on the wired network that has access to the services provided by the Grid. A proxy can provide several services for the proxy based architecture. These services are named Proxy Services and can be deployed or un-deployed on the proxy dynamically based on the requirements of the client applications on the mobile device associated to the proxy. The proxy can execute other programs beside Proxy Services providing for the Mobile Grid. Some of the possible Proxy Services are introduced later in this section. A client application on the mobile device should know the Proxy Services that it needs for its operation. The client asks its proxy to deploy the required Proxy Services and after the deployment of Proxy Services the client application can use Proxy Services to communicate with the resources on the Grid. When the client application is terminated and there are no more client applications using a Proxy Service, the proxy can un-deploy the Proxy Service to free the resources assigned to that Proxy Service. In this way dynamic proxies are created; Proxies provide a dynamic set of Proxy Services that changes according to the requirements of the client applications.

In our approach the application on the mobile device needs to know the address of machines which are currently proxies. The addresses and other information about these nodes are kept in several Proxy Finder Servers. The client application should have the address of at list one Proxy Finder Server and it is the responsibility of the Proxy Finder Server to find the appropriate proxy for a client application. Proxy Finder Servers are also responsible for handling issues related to the mobility of mobile devices and failure at proxies.

PFSs and proxies can be owned by the Grid resource provider that intends to provide its mobile clients with access to its Grid resource. Another possible owner for PFSs and proxies can be a "Mobile Grid Provider". Grid resource providers subscribe to this "Mobile Grid Provider" company to make accessible their recources by mobile clients. In both cases clients can receive the address of PFSs from the provider of their intended Grid resource.

3.1 Proxy Services

Proxies provide services for mobile devices that enable the application on mobile devices to use the resources available on the Grid smoothly even in the presence of disconnections. In this section we describe a set of Proxy Services.

- **Relay** - A role of the proxy can be the relaying of data between an application on a mobile device and the Grid resource. In this case the application on mobile device which is using a service on the Grid submits its request to the proxy. The proxy relays this request to the service and after that relays the results received from the recourse to the client on the mobile device. The Relay Proxy Service is used in the case of occurrence of a disconnection or changing of the proxy.
- **Downscale** - For some applications that have multimedia streaming or the image transmission, the proxy can downscale the traffic with a suitable transmission bit rate to the mobile device according to mobile devices physical specification or the transient condition of wireless communication links. By shifting the task of downscaling to the proxy, services provided originally for powerful desktop machines connected to high bandwidth wired links can be used by mobile devices without any change. One example use of this Proxy Service was shown in the first usecase (section 2.1).
- **Grid Service Discoverer** - The proxy can find the Grid services needed by the client application on the mobile device. The Grid Service Discoverer Proxy Service receives the information about the required service from the client application and tries to find the service by searching its service repository. This Proxy Service can be used in the healthcare domain usecase presented in section 2.1 to find a "Hospital Finder" or "ECG Siganl Analyzer" services.
- **Disconnection Handler** - Failure might happen during a session for several reasons, such as a disconnection between the mobile device and the network or the low battery power of the mobile device. The Disconnection Handler Proxy Service can buffer the results received from the invoked service on the proxy and deliver the result to the client application after the reconnection. In both usecases a Disconnection Handler Proxy Service can be used to buffer the results received from the Grid services on the proxy.
- **Task offloader** - Because of the limited resources on a mobile device an application on the mobile device might want to offload parts of its tasks to the proxy. The proxy processes these tasks locally or it may submit them to a machine with available resources on the Grid.

- **Checkpointing** - The mobile device can send the checkpoints of its running applications to the proxy. This is often necessary since checkpoints may need a good deal of storage which may not be available at the mobile device. The Checkpointing Proxy Service is responsible to manage checkpoints received from client applications.
- **Movement tracker** - This Proxy Service tracks mobile device and can be queried at any time by other Proxy Services to retrieve the current location of the mobile device.
- **Masquerade** - A proxy can create a cluster of mobile devices which volunteer to provide resources, e.g. CPU cycle or storage space for the Grid applications. The proxy can creates a bridge for the cluster. This allows Grid users which are willing to use these available resources see an incorporated resource presented by the proxy [14,19,15]. The Masquerade Proxy Service is responsible for providing a set of services to create an incorporated resource. This set of services can include:
  - Task assignment to mobile devices based on their available shared resources.
  - Task replication to achieve higher reliability.
  - Load balancing among mobile devices to avoid overloading a device while there are other devices with available resources.
  - Failure prediction; The proxy monitors the residual battery power of devices by querying devices or trace their movement to predict a possible failure in near future.
  - Task migration; By predicting a failure the proxy can migrate the assigned task and its associated data from the device close to failure, to another mobile device in the cluster.

3.2 Components Interaction

The detailed description of operation and the interaction between different components of the system are presented in the following subsections.

Proxy Registration at Proxy Finder Servers. The proxy registers at several Proxy Finder Servers in its proximity by providing the information about itself. The information includes the IP address, GPS position and its available Proxy Services. By registering at several Proxy Finder Servers, the resources offered by a proxy can be more widely accessible. Ideally the proxy registers itself in Proxy Finder Servers in its proximity. In this case each Proxy Finder Server has a list of proxies close to it. The information about proxies saved at Proxy Finder Server might be updated by proxies. For example if a proxy decides to dedicate a smaller share of its processing power to the Mobile Grid it informs the Proxy Finder Server that it is registered with.

Find a Proxy. The client application should know the address of at least one or more Proxy Finder Server beforehand. Thus, the mobile device can send a message to one of the Proxy Finder Servers and request it to find an appropriate

proxy. The mobile device should specify what kind of Proxy Services it expects the proxy to provide. The Proxy Finder Server selects a proxy from the list of registered proxies based on a set of input parameters. The first parameter is the geographical location of the proxy; a proxy is chosen which is closest to the current location of the mobile device. The second parameter is the list of available Proxy Services that a proxy is able to provide. By knowing the current location of mobile device and the list of required Proxy Services from the client application on the mobile device, the Proxy Finder Server can select one (or several) proxy (or proxies) and sends a request message on behalf of the mobile device to the chosen proxy (or proxies).

The decision to accept the client is made by the proxy, i.e. the proxy accepts a client's request if it has enough resources to provide services for a new client. To accept a new client the proxy might need to deploy a new Proxy Service or need to download the Proxy Service code and install it. The proxy can accept a new client based of on its available resources and its current load. If the current load on the proxy is too heavy to accept a new client the proxy can decide to reject the request.

If the proxy decides to accept the request it informs the Proxy Finder Server about the acceptance and deploys required Proxy Services (if not deployed yet). Upon receiving the first accept message from a proxy, the Proxy Finder Server sends the address of the proxy to the client application on the mobile device. Afterward the client application can start to use the Proxy Services on the proxy to communicate with resources on the Grid.

Change the Proxy of a Mobile Device. This architecture also supports the change of the associated proxy of a mobile device under some circumstances. The associated proxy to a mobile device may change if the device moves to a location far from the proxy, or the proxy decides to reduce its load in the case of overloading.

The decision of transferring the session of a mobile device to another proxy is made by the proxy. Since the proxy might have other programs beside the Proxy Services it is hosting, it monitors its resources and when it is becoming overloaded or needs more resources for its other programs, the proxy may decide to transfer sessions related to a client to another proxy.

As mentioned before, a proxy can transfer the sessions of a client to another proxy if the mobile device moves to a location far from the proxy. To know if the mobile device is too far from the proxy, the proxy needs to trace the mobile device. The mobile device periodically sends its current location to the proxy. If the proxy notices that a mobile device has moved to a location far from the proxy, it may decide to transfer the session of that device to another proxy closer to the mobile device. It is the responsibility of proxy to find a new appropriate proxy closer to current location of mobile device and transfer its session to the new proxy. The process of transferring the session is transparent to the mobile device, i.e. mobile device sees a continuous service during the transferring process.

Handling the Proxy Failure. To be aware of a failure at a proxy, it is required that the availability of the proxy be checked regularly. Performing this check by

mobile devices associated with the proxy is not a good option, since frequent disconnections may happen between mobile devices and the proxy because of the movement of mobile device or the changing condition of the wireless media. An alternative solution is to assign the task of checking the availability of proxies to the Proxy Finder Server. Whenever a proxy accepts a new request from a Proxy Finder Server the proxy periodically sends a keep alive message to the Proxy Finder Server. On the other hand, if the Proxy Finder Server does not receive a keep alive message after a period of time it assumes that the proxy has failed. In this case the Proxy Finder Server starts the process of finding a new proxy for mobile devices associated with the failed proxy.

4 Prototype

To test the viability of the proposed approach a prototype is implemented. The prototype includes the basic parts of the infrastructure. The Proxy Finder Server is implemented to be able to register the proxies. The functionality of finding an appropriate proxy for requests sent by mobile devices is implemented for the Proxy Finder Server as well. Currently, two proxy services are implemented: Relay and Disconnection Handler. As an example client application, the second scenario described in section 2 is implemented. For the first version of the prototype, GPS coordinates are not used for calculating the distance between components. Instead, a proxy is selected randomly.

The mobile device used in our experiments is an HTC Magic smartphone and Android 1.6 is used to implement the client application on the smartphone. Our experiments includes one machine as the Proxy Finder Server and four machines as proxies. The Proxy Finder Server functionality, the proxy functionality (which includes the registration process) and Proxy Services are implemented as web services. The Apache Tomcat 6.0 is used as our application server on the Proxy Finder Server and proxy machines.

5 Related Work

In the proxy-based approach to creating the Mobile Grid the responsibility of supporting the mobile devices is shifted to the proxy and there is no need to change the deployed Grid middleware. There are several papers published with focus on the proxy-based Mobile Grid architecture that proxy is employed to provide a specific service for specific applications. In some papers the proxy is used as a bridge to the Grid [26,5,3,2,27,12]. The proxy plays the role of a client for the Grid resources on behalf of the mobile device. A light-weight application is installed on the mobile device to be able to communicate with the proxy and there is no need to have the Grid middleware on the mobile device. In several research the proxy is used to offload tasks from the resource constrained mobile devices to more powerful resources on the Grid [16,31,4]. The earlier research on the mobile Grid is mostly focused on making it possible to integrate mobile devices as resource providers to the Grid through a proxy. Resources can be services available on mobile devices or the processing capabilities of the mobile

device. [18] and [11] are examples of this role of proxy. The cluster-based design is used in several research [14,19,23,25,7,22,15,13]. A cluster of mobile devices is created by a proxy node with the aim of hiding the heterogeneity and dynamic nature of the mobile wireless environment from the clients on the wired network. In addition, the proxy-based architecture is used to support multimedia applications on the mobile devices [28,30,17] and for peer-to-peer resource sharing [8,6]. There are also some papers on providing secure communication for mobile devices using a proxy [10,12,6] and also control the level of Quality of Service (QoS) [11,21,12] by monitoring done at the proxy.

In almost all of this work a specific type of applications is targeted and the proxy is designed to support the requirements of that application. In our infrastructure several kinds of application can be supported each one with a related Proxy Service on the proxy. Even in the case of emergence of new applications with new requirements an appropriate Proxy Service to handle those new requirements can be designed and added to the proxies. Another advantage of our approach to the previous work is that the proxies in our infrastructure change based on the demands of the clients. A proxy service is deployed on the proxy if there is a client requesting that service. If a proxy service in not in use by any client that service can be un-deployed to preserve the resources on the proxy.

6 Conclusion and Future Work

The increasing popularity of small digital mobile devices leads to a higher demand to enabling these devices to support various kinds of applications as ones which are available for desktop computers. An obstacle to meeting this demand is limited hardware capabilities of mobile devices. The characteristics of wireless communication also add challenges in using the available Grid resources by the mobile devices. The proxy-based Mobile Grid can support the mobile devices by offloading the compute-intensive tasks from resource restricted mobile devices to the more capable machines on the Grid and also by handling the disconnections appear because of the unreliability of wireless links. In this paper we explained what services should be available at the proxy to meet the requirements of various kinds of applications on a mobile device. An initial version of a prototype and a simple example application are implemented to show the the viability of the proposed approach.

Currently, it is assumed that the set of proxy services available on the proxy machine is fixed. Though, to preserve resources on the proxy, the proxy services available on the proxy can change dynamically. Implementing the dynamic proxies are postponed to the future work. Using the GPS coordinates to calculate the distance between components in the system is planed to be done in the future. Implementation of other proxy services mentioned in section 3.1 and example scenarios that use these proxy proxies are also postponed to the future. To find the overhead added to comunications by using our proposed infrastructure and also performance measurement, several experiments should be disigned and executed. Designing and executing the performance measurement experiments are planned to be done as well for future work.

References

1. Coronato, A., De Pietro, G.: MiPeG: A middleware infrastructure for pervasive grids. In: Future Generation Computer Systems, pp. 17–29 (2008)
2. Khatua, S., Dasgupta, S., Mukherjee, N.: Pervasive Access to the Data Grid. In: The International Conference on Grid Computing and Applications (2006)
3. Singh, A., Trivedi, A., Ramamritham, K., et al.: PTC: Proxies that Transcode and Cache in Heterogeneous Web Client Environments. In: World Wide Web, pp. 7–28 (2004)
4. Rossetto, A.G.M., Borges, V.C.M., Silva, A.P.C., et al.: SuMMIT - A Framework for Coorcinating Applications Execution in Mobile Grid Environment. In: The 8th IEEE/ACM International Conference on Grid Computing, pp. 129–136 (2007)
5. Sajjad, A., Jameel, H., Kalim, U., et al.: AutoMAGI - an Autonomic middleware for enabling Mobile Access to Grid Infrastructure. In: Joint International Conference on Autonomic and Autonomous Systems and International Conference on Networking and Services, pp. 73–73 (2005)
6. Harrison, A., Kelley, I., Mieilica, E., et al.: Mobile Peer-To-Grid Architecture for Paramedical Emergency Operations. In: Proceeding of Challenges and Opportunities of HealthGrids, pp. 283–294 (2006)
7. Huang, C., Zhu, Z., Wu, Y., et al.: Power-Aware Hierarchical Scheduling with Respect to Resource Intermittence in Wireless Grids. In: Proceeding of Machine Learning and Cybernetics, pp. 693–698 (2006)
8. Yang, C., Chen, C., Chen, H., et al.: A Peer-to-Peer File Resource Sharing System for Mobile Devices. In: The 3rd International Conference on Grid and Pervasive Computing Workshops, pp. 275–280 (2008)
9. Coulson, G., Grace, P., Blair, G., et al.: A middleware approach for pervasive grid environments. In: UK e-Science Programme Workshop on Ubiquitous Computing and e-Research (2005)
10. Cho, H., Lee, B., Kim, M., et al.: A Secure Mobile Healthcare System based on Surrogate Host. In: The Sixth IEEE International Conference on Computer and Information Technology (2006)
11. Ohta, K., Yoshikawa, T., Nakagawa, T., et al.: Design and implementation of mobile grid middleware for handsets. In: 11th International Conference on Parallel and Distributed Systems, vol. 2, pp. 679–683 (2005)
12. Racz, P., Burgos, J.E., Inacio, N., et al.: Mobility and QoS Support for a Commercial Mobile Grid in Akogrimo. In: 16th IST, Mobile and Wireless Communications Summit, pp. 1–5 (2007)
13. Choi, S.K., Cho, I.S., Chung, K.S., et al.: Group-based Resource Selection Algorithm Supporting Fault-Tolerance in Mobile Grid. In: Third International Conference on Semantics, Knowledge and Grid, pp. 426–429 (2007)
14. Isaiadis, S., Getov, V., Kelly, I., et al.: Dynamic Service-based Integration of Mobile Clusters in Grids. In: Grid Computing: Achievements and Prospects, pp. 159–171 (2008)
15. Katsaros, K., Polyzos, G.C.: Optimizing operation of a hierarchical campus-wide mobile grid. In: The 18th IEEE Personal In-door and Mobile Radio Communications conference, PIMRC (2007)
16. Trung, T.M., Moon, Y., Youn, C., et al.: A gateway replication scheme for improving the reliability of mobile-to-grid services. In: IEEE International Conference on e-Business Engineering, pp. 456–463 (2005)

17. Mohapatra, S., Cornea, R., Dutt, N., et al.: Integrated power management for video streaming to mobile handheld devices. In: The Eleventh ACM International Conference on Multimedia, pp. 582–591 (2003)
18. Hampshire, A.: Extending the open grid services architecture to intermittently available wireless networks. In: UK eScience All Hands (2004)
19. Phan, T., Huang, L., Dulan, C.: Challenge: Integrating Mobile Wireless Devices Into the Computational Grid. In: The 8th ACM International Conference on Mobile Computing and Networking (2002)
20. Chu, D., Humphrey, M.: Mobile OGSI.NET: Grid Computing on Mobile Devices. In: Fifth IEEE/ACM International Workshop on Grid Computing (GRID 2004), pp. 182–191 (2004)
21. Hwang, J., Aravamudham, P.: Middleware Services for P2P Computing in Wireless Grid Networks. IEEE Internet Computing 8(4), 40–46 (2004)
22. Kim, I.K., Jang, S.H., Lee, J.S.: Adaptive Distance Filter-based Traffic Reduction for Mobile Grid. In: 27th International Conference on Distributed Computing Systems Workshops, pp. 8–8 (2007)
23. Katsaros, K., Polyzos, G.C.: Evaluation of scheduling policies in a Mobile Grid architecture. In: International Symposium on Performance Evaluation of Computer and Telecommunication Systems (2008)
24. Foster, I., Kesselman, C.: The Grid: Blueprint for a New Computing Infrastructure. Morgan Kaufmann, San Francisco (1998)
25. Park, S., Ko, Y., Kim, J.: Disconnected Operation Service in Mobile Grid Computing. In: Orlowska, M.E., Weerawarana, S., Papazoglou, M.P., Yang, J. (eds.) ICSOC 2003. LNCS, vol. 2910, pp. 499–513. Springer, Heidelberg (2003)
26. Koufi, V., Vassilacopoulos, G.: HDGPortal: A Grid portal application for pervasive access to process-based healthcare systems. In: Second International Conference on Pervasive Computing Technologies for Healthcare, pp. 121–126 (2008)
27. Messig, M., Goscinski, A.: Autonomic system management in mobile grid environments. In: The fifth Australasian symposium on ACSW frontiers, pp. 49–58 (2007)
28. Huang, Y., Mohapatra, S., Venkatasubramanian, N.: An energy- efficient middleware for supporting multimedia services in mobile grid environments. In: International Conference on Information Technology: Coding and Computing, vol. 2, pp. 220–225 (2005)
29. Rao, S., Kiran.Kasula, V.D., Bano, S.: Management Study of Layered Architecture to Incorporate Mobile Devices and Grid Computing. In: Novel Algorithms and Techniques In Telecommunications, Automation and Industrial Electronics, pp. 123–127 (2008)
30. Huang, Y., Venkatasubramanian, N., Wang, Z.: MAPGrid: A New Architecture for Empowering Mobile Data Placement in Grid Environments. In: Seventh IEEE International Symposium on Cluster Computing and the Grid 2007, pp. 725–730 (2007)
31. Guan, T., Zaluska, E., De Roure, D.: Extending Pervasive Devices with the Semantic Grid: A Service Infrastructure Approach. In: The Sixth IEEE International Conference on Computer and Information Technology, pp. 113–113 (2006)