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Toward the Mobile Grid: Service Provisioning in a Mobile Dynamic Virtual Organization

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Abstract

When considering mobile or nomadic users of commercial grid services, today's grids have to be reflected with regard to potential functional extensions needed, as well as emerging consequences on business modeling. In-line with a formalized investigation of such mobile grids, the concept of a mobile dynamic virtual organization (MDVO) is introduced, and relevant potentials are illustrated by means of a business scenario in e-health and tourism.

1. Introduction

Grid computing receives a constantly growing attention as it has turned out to be a well suited environment for complex problem solving or data storage. Bringing a commercially oriented cooperation model into grid computing enables the transition from previous research, such as community-orientation, to new fields of applications. Typical grid application domains include tasks in the area of high performance computing (HPC), such as climate modeling [1]. Recent approaches, however, focus more on knowledge-intensive, adaptive workflows with the intent to adapt grid computing for instance toward e-health or disaster handling [2]. Grid architectures, thus have to consider adjustments with respect to trust building mechanisms, security in general, and accounting methods in order to support new or adapted business models. Besides those extensions, next generation grids will have to reflect another important shift towards the integration of mobility aspects. While today's grids mostly consist of fixed resources, it is rather obvious that the need for mobile grid resources rises together with people's ever-growing mobility.

Both areas, commercialization and support of mobility, impose demanding changes in the design of grid-based solutions. For commercialization, grid economics have to be investigated with respect to an understanding of prevailing market structures, grid-specific commodities, and participating grid players [3]. For mobility, the major challenge lies in integrating actively contributing mobile grid nodes into a grid infrastructure that focuses on fixed nodes. Thus, mobile grid nodes are seen as resources being able to consume and to provide services. From a business process viewpoint, this implies also that mobile nodes can be involved directly in workflow activities. Thus, mobile grids have to overcome content delivery, portal-based approaches for extending grids by mobile devices [4]. The respective changes to a grid architecture have to be reflected on one hand from an economic point of view, while on the other hand, they come inseparably connected with technical requirements on the underlying infrastructure. Accordingly, this paper defines *mobile grids* by distinguishing grid computing from related concepts. *Mobile dynamic virtual organizations (MDVO)* are introduced as extended virtual organizations (VO), and advantages of mobile grids in the sense of *added values* are developed. The remainder of this work is structured as follows: Section 2 compares grid computing with related fields, which leads to a description of key features of mobile grids in Section 3. Thereupon, a mobile grid business scenario is analyzed in Section 4. Section 5 finally shows the value addition in mobile grids, followed by a summary and conclusions being drawn in Section 6.

2. Related Work

Grid computing, and thus also mobile grid computing, can not be distinguished in the first place without ambiguity from related concepts [5]. These include service-oriented architecture (SOA) and peer-to-peer (P2P) systems [6]. In order to reach a better notion of these concepts they are described and compared by means of major business and technical metrics [7], which natively show interdependencies; such as for example the criteria "Ad-hoc Formation" both implies economic and technical aspects, whereas it is perceived in this specific case from a business-oriented viewpoint, thus characterizing administrative or financial arrangements to be taken before a system is operational. As investigated in detail in [7], grid systems, SOA, and P2P are contrasted as shown in Table 1 with respect to business metrics and Table 2 for technical metrics.

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Table 1. Business Metrics Characterization of Grid, SOA, and P2P Systems

Category[a]			Commercial Usage	Efficiency	Inter-domain Service Provision	Quality-of-Service	Resource Coordination	Resource Sharing	Scalability	Service Aggregation
Grid Systems	Grid Computing	X	0	+	0	X	0	X	0	0
Grid Systems	Service Grid	+	X	+	X	X	X	0	0	X
Grid Systems	Mobile Grid (Knowledge Grid)	+[b]	X	X[d]	X	X	X	0	X	X
SOA		0	X	0	0[e]	+	+	0	0	+
P2P Systems		X	+[c]	X	+	0	0	X	X	0

a. "X" marks an attribute that is relevant and exists in the system in question; "+" denotes an aspect being relevant, however, not existent in current designs or implementations; "0" is considered as not being relevant for a system.
b. Dynamicity is limited to mobile or nomadic grid nodes only.
c. Research on suitable business models for P2P systems is ongoing, whereas existing P2P systems typically are set in a non-commercial environment.
d. Handling of scarce resources, such as bandwidth or computational power, is a key issue for mobile grid nodes. Accordingly, efficient use of available resources is a vital key success factor for a mobile grid.
e. SOA provides for service provision across administrative domains, however due to missing service aggregation and service coordination functionality, formation of virtual organizations is not supported.

Table 2. Technical Metrics Characterization of Grid, SOA, and P2P Systems

Category[a]			Decentralization as Design Goal	End-to-end Connectivity	Interoperability	Location Transparency	Robustness	Standards	Storage
Grid Systems	Grid Computing	X	0	0	X	X	0	X	X
Grid Systems	Service Grid	X	0	0	X	X	0	X	X
Grid Systems	Mobile Grid (Knowledge Grid)	0[b]	0	0	X	0[d]	+	X	X
SOA		0	0	X	X	X	0	X	0
P2P Systems		X	X	X	+[c]	+[e]	X	+[f]	X

a. Parameter values as described in Table 1.
b. Mobile grids potentially also offer high performance computing functionality, these services however are assumed to be included by a traditional grid operator.
c. Interoperability of different P2P systems is usually not supported.
d. Mobile grid services are supposed to consider location and context information.
e. Focus on decentralization implies the absence of central elements such as a service registry.
f. Community-wide standards only.

3. The Nature of a Mobile Grid

Due to their strong focus on inter-domain service provision and service virtualization, grids are organizationally reflected by virtual organizations (VO), also referred to as virtual enterprises or virtual communities. The concept of VOs is manifold and its notion has evolved over time [8] [9]. With regard to a commercial, grid-oriented comprehension of VOs, such as presented in [10], VOs are considered *to allow for information and communications technology-supported, accountable and chargeable resource coordination across administrative domains, incorporating mechanisms for parameterizable secure authentication and authorization*. When defining mobile grids, however, this concept of VOs has to be altered in order to account for dynamically joining and leaving nodes as well as for nodes that are not bound anymore to a fixed location. By doing so, the concept of VOs itself remains unchanged, an extended view of VOs however is needed. This is caused by the fact that VOs have been agnostic of whether nodes are fixed or mobile, since up to present only the first was considered in grid computing by tradition. For that reason, MDVOs are introduced as a respective extension of VOs, whereas dynamicity in a mobile grid primarily is assumed to be evoked by mobile grid resources. In order to emphasize this dependency, the concept of VOs is altered by explicitly mentioning mobility and dynamicity. Accordingly, *MDVOs are virtual organizations whose members are able to change locations while provided or consumed services remain available even after temporary loss of reachability, and while running or yet to be initiated workflows adapt to changed conditions, so that MDVOs are characterized by a strong dynamic element with respect to their organizational composition and their business processes*. Not all members have to be mobile in order to denote a VO as an MDVO. If a VO however, allows at least for a subset of its members to change locations and still being able to profit or to provide services while moving, such a VO is regarded as an MDVO. Mobile or nomadic organization entities on one hand augment an MDVO with respect to altered context information and by widening the geographical range of service provision on scene. On the other hand, mobility support imposes non-trivial problems to be solved on both, organizational and infrastructure's level. For instance, as mobile members might temporarily find themselves uncovered by a communications network infrastructure, an MDVO's session model has to envision resumption of partly completed tasks when network coverage is available again. Mobility consequently shows a strong influence on the dynamic element in MDVOs. With changing environment grows the demand for adaptive workflows that are able to react on modified influence parameters. As members may join or leave the organization, need for a managing and supervising entity arises during members' active existence in a VO. Even though a fully decentralized, peer-to-peer system-alike organization remains imaginable, a commercial mobile grid is assumed to rely partly on centralized components, being incorporated into the role of a VO manager. Based on these characteristics of MDVOs and the comparison of grids, SOA, and P2P systems (cf. Section 2), a set of usability criteria for mobile grids has been developed, each constituting 1 main and 2 subordinated checkpoints.

- Field of Application: A chosen application domain has to be suitable for mobile grids. This is provided if a field of application first is characterized by mobile or nomadic users and secondly deals with complex problem solving with a focus on knowledge-intensive tasks to be conducted.
- Business Model: Respective business models have to be able to benefit from mobile grids' characteristics. This especially is the case if various, legally independent organizations provide services that form together integrated business processes. Besides multi-domain service provision, a business model has to provide for centralized elements, such as a VO managing entity.

Mobile grids focus on solving complex problems by exploiting knowledge as their main input factor. High performance computing facilities become less important than in traditional, fixed grid systems. Data and computational power are still regarded as being helpful; they however are rather accessed via computational or data-related services that are offered by a dedicated fixed-grid service provider than being considered as a core competence in the mobile grid itself. In contrast, a mobile grid's core competence is found in extending the range of complex, adaptive business processes onto mobile nodes, technically represented by mobile devices, being operated by a human being.

4. Business Scenario Development

To visualize a typical mobile grid implementation as a detailed example, the respective business scenario in the application domain of e-health and tourism has been developed [7]. This domain has been chosen as it shows key requirements that fully match those criteria for adopting mobile grids (cf. Section 3): Travelers embody mobile or nomadic users and e-health deals by definition with non-trivial questions, especially when patients are abroad, finding themselves in an environment they are unfamiliar with. Furthermore, the scenario sketches a mobile grid-based travel insurance solution in which an insurance company acts as a service aggregator for its roaming customers. The insurance company, thus, takes a central role with respect to business process execution while various, organizationally and legally independent, third parties are involved as grid service providers. For an insurance company, two main arguments for offering mobile grid-backed travel insurance exist:

- By means of the offered e-health services, a traveler easily is able to decide whether or not a medical condition indicates the consulting of medical facilities, thus, resulting in an overall lower number of unnecessary and costly consultations.
- In the case of infectious diseases, like malaria, early diagnosis and initiation of the therapy show a positive effect in the treatment as a whole with respect to associated costs and duration of illness.

With regard to actor and role models, 3 structural levels are considered, consisting of organizational, grid services and network perspectives, respectively. Seen from an organizational viewpoint, key players consist of the insurance company, the insured travelers, and possibly several tiers of third parties. The insurance company hereby offers travel insurance to its customers and sources services from specialized third parties which again can buy services from second tier third parties and so on. One, but possibly multiple business roles are assigned to each player. Mobile travelers are the only completely dynamic VO members as they probably join and leave a VO spontaneously. Under these circumstances, a VO has to support different types of mobility, such as user, terminal, and service mobility [11]. Figure 1 outlines the respective scenario-specific, explicitly

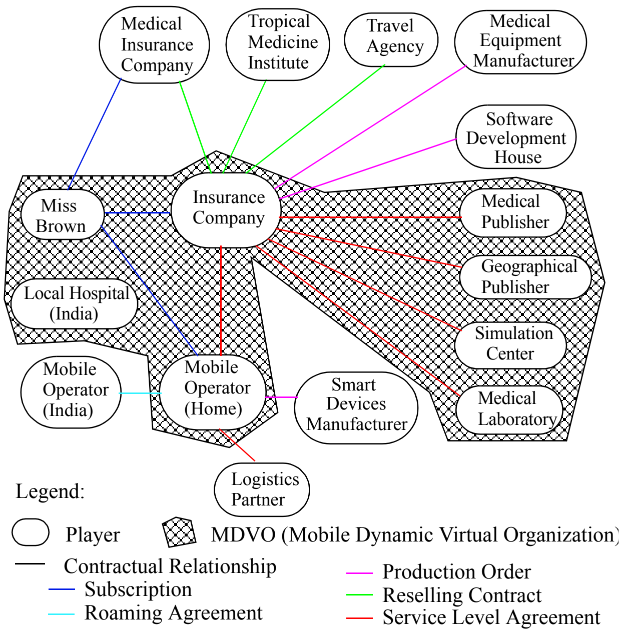

Figure 1. Organizational Alignment of Business Scenario Players

mentioned and assumed to be present players together with maintained contractual relationships. Interactions between players are combined to adaptive electronic workflows, which again are integrated into business processes. Interactions consist of different types of business flows, such as information, financial, and product flows. Figure 2 shows exemplarily on the basis of a business process the respective analytic steps.

While role models are complex when sketched from an organizational viewpoint, from a grid services' perspective fewer roles are identified. For an existing grid service platform, roles embrace platform provider, platform operator, service providers and service consumers. This limited range of possible business roles is caused by an exclusive focus on grid services. Everything electronically provided is seen as a service, i.e. a well-specified functionality that is offered through a defined interface. In contrast to organizational considerations, services with corresponding interfaces and protocols for information exchange are centered. Entities are no longer represented by actors such as companies or humans, but by resources only.

From a network perspective, the main goals are to provide access to communication services for correctly authenticated and authorized users as well as to reliably account network service usage. This viewpoint differs from organizational and grid service considerations in the way that corresponding role models appear in the first place to be purely technology-centered. Network-relevant role

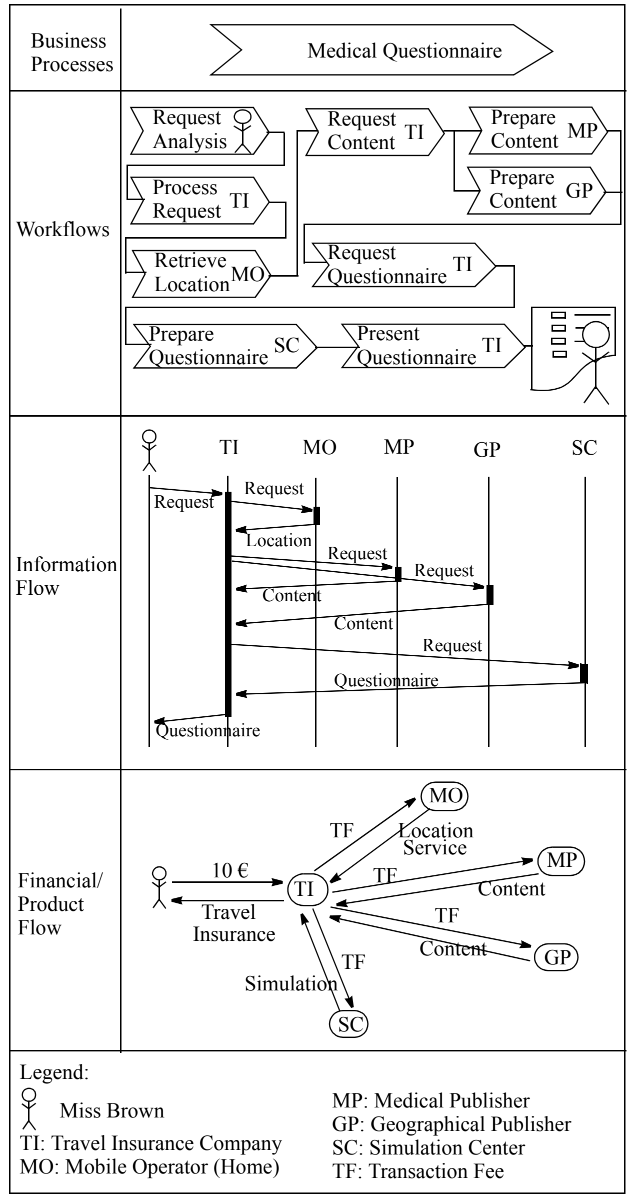

Figure 2. Business Flow Analysis for Exemplary Business Process

models however embrace more various role types than grid service role models, which leads to increased possibilities of cooperation and thus causes business aspects to be of equal interest as technical considerations. These business roles consist of network infrastructure providers, network operators, communication service providers and network service consumers.

5. Value Addition Through the Mobile Grid Approach

In a mobile grid, it is possible to transmit content to a mobile grid node whenever needed as well as to send back processed content. This content has to fulfill two requirements. First, it is adapted to the mobile device's capabilities and secondly, it takes the device user's current situation into account. An important means for fulfilling these requirements is the support of non-trivial service qualities that allow subtle charging schemes and QoS-bundles according to device capabilities and business models.

Determined by the respective usability criteria, the mobile grid approach is applicable to a wide field of domains. The business scenario presented shows exemplarily, how travelers abroad are able, on the one hand, to provide services, for instance by means of metered data, and on the other hand, how they can access complex, knowledge-intensive services, that are composed in an MDVO by a service aggregator depending on a service user's current needs. Practical benefit results for all involved actors, if underlying business models are designed accordingly. The travel insurance company is able to differentiate from its competitors by offering an understandable product for their customers being available on site exactly when needed. In turn, travelers profit from a solution that reflects their individual needs while delivering medical advice in a familiar, homelike manner. According to the type of partnership with a grid solution provider, mobile network operators open up either new means of transaction-based income streams or they can take over further services, such as customer management or billing. Service and content providers can concentrate on providing their services efficiently by focusing on core competencies only. They thus profit from increased efficiency by means of specialization. A service provider of one VO can offer the very same or a similar service to another VO. Hereby, the potential for economies of scale is gained. While providing services, know-how is exposed in fragments only — the service provider keeps full control over its resources and is protected against competitors copying the service.

6. Summary and Conclusions

An extensive comparison of grid computing, SOA, and P2P systems, regarding relevant business and technical metrics, has led to an advanced understanding of grid systems. This investigation provided the key basis for characterizing commercially oriented mobile grid systems, which are perceived as an enhancement of grid computing with respect to their support of mobile and nomadic grid resources. Accordingly, MDVOs have been introduced as an extension of VOs with added functionality in terms of dynamicity and mobility. Moreover, determined usability criteria for mobile grids have been tested in a travel insurance scenario. By analyzing this scenario on the organizational, grid service, and network level, respective role models were defined. Based on a detailed analysis and the proposed business flows the added value through mobile grid systems has been identified.

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