Towards a Market-Centric OGSA-Compliant Architecture Model

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Abstract: The Open Grid Services Architecture (OGSA) provides a high-level framework for service-oriented grid architecture, mostly based on web service standards. The vision of a worldwide computing grid evokes the scenario of electronic markets for grid services. The object of our investigation is a service-oriented grid architecture model that is compliant with the OGSA specification. We address the problem that the OGSA specification does not meet economic requirements of grid markets explicitly, because it has been designed for other, technical objectives. The problem is investigated from an e-business transaction perspective. The contribution of this paper is a market-centric extension that combines OGSA with market services which meet economic requirements revealed from the investigation perspective.

1 Introduction

The Open Grid Services Architecture (OGSA) [Fo06] provides a high-level framework for service-oriented grid architecture, mostly based on web service standards. Grid technology is an emerging field and potential use cases are broadly based [Sm04]. Once electronic markets for grid services become reality, they will be different from existing grid application approaches. Instead of mid- or long-term business relationships, which are formed manually, they will provide means for automatically matching service providers and requesters. In markets with prevailing short-term business relationships, increased automatization and standardization offer potential for lowering transaction costs. Operational definition of a service as part of a contract between a service provider and a service consumer are essential in business relationships. These are provided by service level agreements (SLAs): explicit formal statements of the obligations and guarantees regarding grid services in a business relationship [Ve99, pp. 1-5]. Grid-related SLA approaches aim at providing an abstraction of the service while facilitating measurement and monitoring of service properties agreed upon [CFK04, pp. 6-7].

This paper deals with service-oriented grid architecture models that are compliant with the OGSA specification [Fo06]. The problem we address is that the OGSA specification does not meet economic requirements of grid markets explicitly, because it has been designed for other, technical objectives. We investigate the problem from an e-business transaction perspective.

In prior work, we have evaluated technical SLA representation approaches and standards relevant for the grid area [KK07]. The contribution of this paper is a market-centric extension that combines OGSA services with market services which meet economic requirements revealed from the investigation perspective. The resulting architecture model for service-oriented grids provides close integration of market services with existing OGSA services. Our approach facilitates substitution and extension of existing OGSA scope services with market-based equivalents.

The paper is structured as follows. Section 2 discusses related work. Section 3 provides relevant details about OGSA, the object of our investigation. In section 4, we provide details of the e-business transaction model that will be further used in our analysis and design considerations. In section 5, we analyze and extend the OGSA specification from the selected perspective. In section 6, we demonstrate the applicability of our model in a selected use case. Finally, section 7 discusses our findings and points out to future avenues of research.

2 Related Work

Related work can be found in the areas of grid market engineering, economic models for resource management and scheduling in grids, and especially infrastructure architectures for grid markets and market-based resource allocation. Other existing resource management and scheduling approaches for computational grids (e.g., Condor [LLM88]), GRAM [Cz98], SNAP [Cz02]) do not consider economic efficiency and thus do not provide incentive to consume resources efficiently [Au04, p. 2].

Investigations of economic resource allocation mechanisms are a building block for grid market engineering approaches. Market-based resource allocation mechanisms are a promising alternative to common cluster computing algorithms, allocating resources in an economically efficient manner. Schnizler et al. [Sc06] provide an auction mechanism including evaluation for resource allocation in the grid. Similarly, Neumann [Ne07] defines a market mechanism for trading resource-near raw services. The former two approaches follow principles of structured market engineering [Ne04]. However, these approaches consider standardized resources in commodity market models only. Eymann et al. [Ey06] consider both a centralized market for standardized resources as well as a decentralized mechanism for an application service market. Principle architectural differences of economic, hierarchical, and abstract owner model approaches for resource discovery and scheduling are discussed in [BCD00]. Efficiency of resource allocation in commodity markets and Vicrey auctions, sealed-bid second-price auctions, for CPU time and disk capacity in a grid are investigated by Wolski et al. [Wo01]. Different economic models for resource management and scheduling in grids, models for interaction, and necessary infrastructures are discussed in [Bu02].

The Spawn system [Wa92] allows trading of standardized computation resources of heterogeneous workstations in Vickrey auctions. Nimrod-G [ABG02] provides a framework for managing resource discovery, trading, scheduling, and execution based on economic principles.

OCEAN (Open Computation Exchange and Arbitration Network) [Pa03] aims at providing a scalable market-based infrastructure for high-performance computing environments. Bellagio [Au04] provides means for resource discovery and market-based resource allocation based on combinatorial auction bids for heterogeneous (non-standardized) resources. Ardaiz et al. describe a grid market based on the catallactic market mechanism together with details about the corresponding infrastructure in [Ar06].

The review of related work shows that a generalized integration of market services into OGSA-compliant grid architecture has not yet been addressed. Similar approaches utilize OGSA as a middleware, infrastructure for actual grid market architecture, which conflicts with the service-oriented architecture (SOA) paradigm of OGSA. Existing market models can be applied to more concrete architecture models that show the applicability of our approach.

3 Open Grid Services Architecture (OGSA)

The Open Grid Services Architecture (OGSA) provides a high-level framework for service-oriented grid architectures, mostly based on web service standards. Figure 1 visualizes the OGSA framework. The building blocks are means for homogeneous access to heterogeneous distributed resources in the grid fabric, as well as a SOA providing higher-level functionality. This functionality of the OGSA is described in the specifications' capability descriptions. We only discuss the services that are most relevant for our architectural considerations and the selected use case briefly in the following. For a detailed description of the OGSA services the reader is referred to the specification [Fo06].

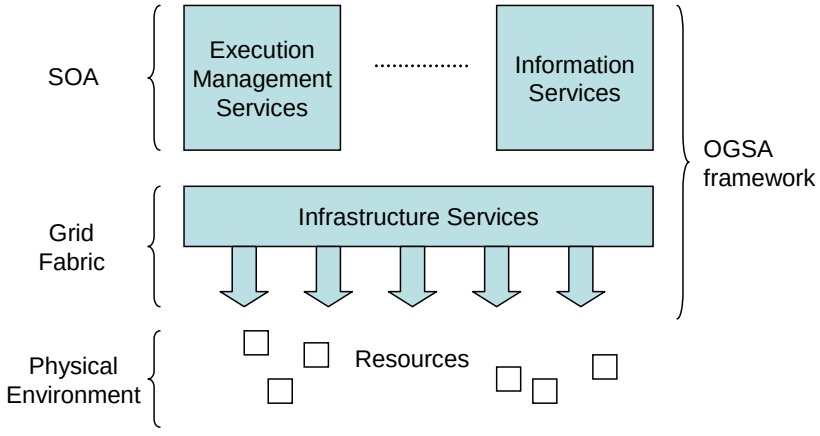

Figure 1: OGSA Framework

Execution Management Services (EMS) constitute the most relevant OGSA capability for resource allocation and scheduling. They include: (i) service containers which encapsulate running entities; (ii) Job Managers (JMs) which are high-level services, encapsulating execution of sets of jobs; and selection services which consist of (iii) execution planning services (EPS), (iv) candidate set generators (CSGs), and (v) reservation services.

Information services provide metadata of resources. In our approach, we imagine market relevant metadata available of resources to be e.g. references to an offer on a market. For example, a grid service may be discovered with existing mechanisms that do not support SLA-aware queries. The information services can then be used to obtain further information about the resource's terms of use, price, etc. *Data services* provide management, access to and update capabilities for data resources. In addition, they are concerned with transfers of data between resources.

4 E-Business Transactions

Transactions on traditional as well as electronic markets correlate with a finite number of interactions between the market participants. Classes of grouped interactions form phases of a transaction [SL98, p. 1]. The sub-processes within such a phase will hereafter be referred to as activities. We extract the activities of encapsulated interactions for both customer and supplier as described in the model by Schmid and Lindemann [SL98].

The original model contains two more activities which precede the browse activity, namely gathering information concerning the general business environment and technology. In the following, we do not consider these activities as they are not directly related to a particular transaction and do not offer significant automatization potential beyond unspecific browse activities. Further, we have split the agreement phase from the original model into a negotiation and a contracting phase. Firstly, this further specifies the order of interaction activities as different activities in the same phase do not have a fixed order. Secondly, contracting is technically non-trivial and substitution of a market partner in complex business relationships may require contracting on the basis of negotiations with the preceding market partners. However, the phase split does not alter compatibility with the original model besides terminological differences but provides a concretization. Table 1 shows the results from the outlined considerations.

Table 1: Phases of a market transaction (following [SL98])

Name	Definition	Activities	Result
Information phase	Gathering information about (i) market participants and (ii) goods and services.	B – browse: search for market partners	List of suppliers/ customers
		O – offer: make an offer	
Negotiation phase	Negotiations between customer and supplier concerning a matching offer revealed in the information phase.	N – negotiation: determine service properties and price	Preliminary agreement
Contracting phase	The parties agree on mutual commitments.	C – contracting: conclude a contract	Contract
Settlement phase	Delivery of goods/services and payment; all necessary operations agreed upon are performed.	D – delivery: delivery of goods and/or services	Fulfillment of mutual commitments
		P – payment: payment of goods and/or services	

5 Market-Centric Grid Architecture

Our approach is based on OGSA and extends the model with market services. The following describes requirements for these services resulting from the selected e-business transaction perspective on OGSA-compliant grid architecture models. In principle, most of the identified requirements apply to electronic SOA markets in general. Afterwards we provide a high level description of market services which have been identified to be necessary to fulfill the requirements, followed by a discussion of the resulting unified architecture model.

5.1 Market-Based Requirements

Technical requirements for OGSA are elaborately discussed in the OGSA specification [Fo06, p. 5 et seq.]. Thus, we only discuss additional requirements which stem from the selected perspective. As a preliminary conceptual requirement, different market models have to be supported by the architecture model. In the resource management area, commonly used models include [Bu02, p. 6]: (i) the commodity market model; (ii) the posted price model; (iii) the bargaining model; (iv) the tendering/contract-net model; (v) the auction model; (vi) the bid-based proportional resource sharing model; (vii) the community/coalition/bartering model; (viii) the monopoly and oligopoly. The selected e-business transaction model leads to requirements from the activities of the phases which have to be supported by the architecture model:

- *Browse* activities require market participants to provide or request information about potential business partners. In contrast to the execution candidate matching scope of OGSA, this requires a market-based extension that reveals candidates potentially beyond existing virtual organizations (VOs). After a binding agreement (SLA) has been established, the customer will have access to the provider's resources in a VO. The problem is, however, that this VO can in principle not always exist a priori. A provider may also prefer to hide details about her infrastructure. Additionally, the market-based revealing of execution candidates must not consider matching of technical aspects only (i.e., "where is it possible to execute a unit of work?"), but also economic aspects (e.g., "where is it possible to execute a unit of work for a certain amount of monetary units?").

- *Offers* can include technical, timely, as well as economic aspects. Formulation of offers requires a suitable offering, respectively bidding language specification. This is a challenging aspect regarding the diversity of possible market mechanisms. Plans of execution have to be built, respecting economic aspects. These schedules, mapping relations between units of work and resources, have to especially respect the economic constraints included in the corresponding offers.

- *Negotiation* activities have to be supported in different ways. For example, auctioneer functionality has to be provided for auction market models. Negotiations can include economic aspects in addition to technical Quality-of-Service (QoS) as well as other functional and non-functional requirements of the traded resources. Further, negotiations have to span over different administrative domains. Negotiation protocols strongly depend on the market mechanism as well as offer and contracting activities.

- *Contracting* activities between providers and customers, defined in SLAs, have to include technical as well as economic aspects as we have discussed in preliminary work [KK07]. SLAs can be established differently depending on the economic market model. For example, immediate resource allocation mechanisms require SLAs to be established end-to-end instantly without further interactions after an offer has been made; though direct interactions between the market participants may also be required for contracting activities in other market models.

- *Delivery* of resources agreed upon, although of major importance, does not raise significant additional requirements from an e-business perspective on existing OGSA services. Service provision, monitoring in terms of logging, as well as details about the required trust relationship are included in the OGSA specification. Thus, the relevant aspect of the delivery activity from our perspective is qualitative and quantitative information about service level attainment, fulfillments of SLAs. The actual information gathering is covered by OGSA.

- *Payments* are managed by services for billing and accounting. Although identified as critical for its success, these services are explicitly undefined in the OGSA specification [Fo06, p. 26]. These services offer functionality as liquidity checking and charging for reservations and especially delivery.

5.2 Market Services

In our approach, *market services* provide means for e-business transactions beyond the scope of the OGSA specification, fulfilling the identified requirements. However, they strongly depend on existing services in the OGSA model. In detail, we have identified the following additional essential services:

- Market-based selection services:

  (i) *Browse* activities are supported by Business Partner CSG (BPCSG) services which can also provide product catalogue like functionality in terms of querying submitted offers.

  (ii) *Offers* can be further processed by market-EPS which potentially include automatic allocation, matching of resource requesters and providers, and schedule creation, e.g., in commodity model markets. Depending on the market mechanism, offers can for example be formulated as WS-Agreement [An07] offers, which fits well into the web service foundation of OGSA [Fo06, p. 16].

- Contracting services manage SLAs and can provide a typical entry point to the market. Depending on the economic model used, this can include:

  (i) *Negotiation* services, e.g., supporting auctioneer functionality or negotiations conform to WS-Agreement.

  (ii) *Contacting* services which cover SLA lifecycle management as well as service level management including reservation aggregation of lower level reservations, respectively service levels agreed upon.

- Billing and accounting services can provide liquidity checking functionality and are notified about d*elivery* of resources and service levels provided, SLA attainment, to enable *payments* to be made in terms of charging the customer and crediting the provider for delivery and possibly for reservations.

These services will interact with OGSA scope services. For example, automated reservation on binding bids have to be mapped to reservation services. This can also include billing and accounting services for charging the customers for reservations. In addition, they can substitute existing functionality, e.g., EMS-like functionality as providing a list of possible execution candidates (resources) for a certain unit of work. Market services also have to utilize means to express SLAs once they are bindingly established between parties. Further, several instances of a market service can independently exists concurrently in a concrete architecture, e.g., representing different markets and possibly allocation mechanisms.

5.3 Market OGSA

The market services provide functionality that is on OGSA services' level, stemming from the SOA paradigm, though different levels of abstraction and interfaces also exist in OGSA (cf. §3). The physical infrastructure level represents utilized hardware with low level interfaces (e.g., SNMP). Infrastructure profiles define infrastructure interfaces (e.g., WSRF) that have to be implemented by services to participate in an OGSA-compliant grid. The infrastructure services, also referred to as grid fabric, build the basis for services providing functionality beyond access to resources. In contrast to other approaches, we do not consider OGSA as a middleware, since the architecture is not layered. Although OGSA services may provide essential functionality, only the infrastructure services provide an underlying platform as shown in Figure 2. In this architecture model, market services can interact with, and provide functions of OGSA services on the same level of abstraction. For example, a candidate set generator can be substituted by a market-centric equivalent (BPCSG) towards broadening the possible candidates for execution beyond the resources currently accessible. Similar to OGSA, the architecture model does not force a system to include all market services, resulting in advanced flexibility and robustness for different use cases. Market services utilize other OGSA services from the infrastructure and function level. Direct access to resources is limited to OGSA infrastructure services.

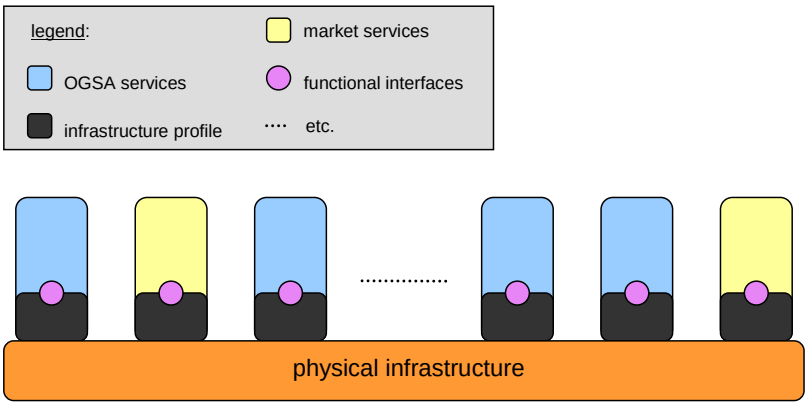

Figure 2: OGSA with Market Services in a SOA

6 Use Case

There is a broad variety of market-based resource allocation approaches in literature. An overview of approaches is provided in e.g. [Ne07, p. 6]. We have selected a grid market with periodic double auction (call market). On this market, resource customers and providers trade standardized resources (commodity market model). Non-executed orders have to be stored in distinct order books for each standardized resource. The use case is similar to a subset of the variations describes for the “resource market” by Eymann et al. in [Ey06].

Figure 3 illustrates an exemplary execution sequence in the use case example: bids are places to the negotiation services by customers (0) and providers (1). The negotiation services use data services (2) to store the bids in order books (3). Once the auction period has expired, the negotiation services inform the market-EPS (4) which call the BPCSG (5). The BPCSG invocation constitutes the *browse* activity in the example and calls the data manager (6) to provide the relevant data which the data manager gets from the order book (7). The market-EPS perform resource allocation and provide information about winning *offers* to contracting services (8), as well as about matching and expired offers to the data services (9) to update the order books (10). The resource allocation represents *negotiation* activities. As the offers represent binding bids, there is no explicit direct end-to-end *contracting* activity. The contracting services inform providers (11) and customers (12) about established SLAs. The billing and accounting services are informed (13). Access to the acquired resources is *delivered* to the customer; i.e., access to the resources is provided to the customer (14). The latter as well as monitoring is within the scope of OGSA. The monitoring of the delivery’s service level is monitored and the billing and accounting services are informed accordingly. Finally, the *payment* is realized by charging the customer (15) and crediting to the provider (16).

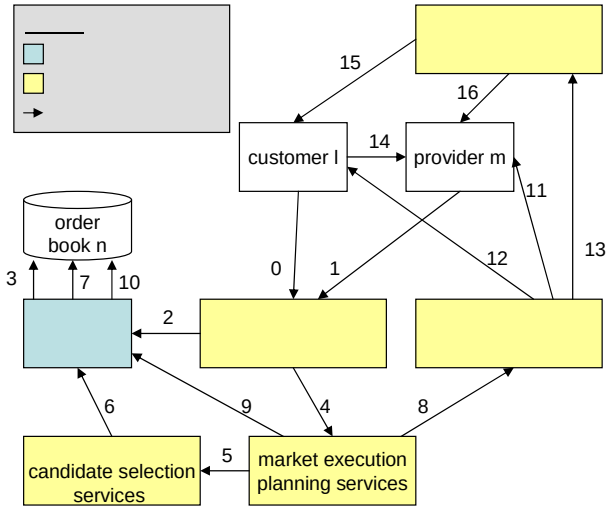

Figure 3: Use Case Execution

7 Conclusion and Future Work

The contribution of this paper is a market-centric extension that combines OGSA with market services which meet economic requirements revealed from the investigation perspective. In addition, the architecture model is designed with respect to the OGSA specification and the requirements included therein. This allows easy integration of the initial concept with services that have been neglected primarily for the sake of simplicity, e.g., security services, in more detailed investigations. Further, the architecture model does not force a certain market mechanism or interaction (e.g., SLA negotiation) protocol which provides flexibility for different use cases. The strict application of the SOA paradigm provides adaptability to changing or additional requirements and allows trading of OGSA core services.

The use case initially proves applicability of our model, though more detailed research of the applicability with relevant market mechanisms is required. Investigations are also required regarding comparisons to existing approaches to gain deeper insight about assets and drawbacks of the seamless integration of market services with OGSA services in a SOA. Further details on interactions of the market services described with monitoring services are required. Billing and accounting services are a key aspect for the success of OGSA and especially our market-centric extension. Therefore, more concrete investigations of these services are essential. The revealed requirements are limited by the selected perspective: further details of requirements, e.g., regarding billing and accounting services, are not discovered from the selected perspective.

Besides a clarification of the interaction with all OGSA services future research is required regarding details about service level attainment monitoring; negotiation protocols; and further market-based resource allocation mechanisms, especially for non-standardized resources. Different resource allocation mechanisms and negotiation protocols have to be investigated, especially with regards to compatibility with our architecture model. Another key aspect of business relationships in SOA is SLAs; further work has to be done investigating details about SLA management in our architecture model.

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