# Description Languages and Market Mechanisms for Trading Grid Services

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**Abstract:** Along with the growth of Grid infrastructures, ubiquitous service provision and consumption has received wide attention in literature and practice. Although the number of available services rises rapidly, concepts and standards for an economical efficient service allocation remain in their infancy. Most proposed mechanisms lack of an interdisciplinary analysis that accounts for economical and technical requirements of the underlying trading objects. In this paper we reduce this gap by introducing concepts and prescriptive languages for describing IT services as trading objects. The contribution is a thorough and innovative classification of potential trading objects in Grid markets, an analysis of formal languages to describe these objects and an evaluation of potential market mechanisms for trading them.

## 1 Introduction

The Grid is an emerging technology for providing access to distributed computational capabilities. Computational tasks can be performed ad-hoc by other resources in the Grid that are not under the user's control. The specification of open standards that define the interactions between different computing resources represents a significant milestone in this development. With the Open Grid Service Architecture (OGSA), the Grid Community has laid the foundation for future developments. OGSA defines computer and storage resources as well as networks, applications and databases as services, i.e. network-enabled entities that provide certain capabilities. Thinking of resources as services paves the way for interoperability among heterogeneous computing and application environments and results in service-oriented systems [FK04].

Current Grid middleware provides the technical infrastructure that allows the sharing of services over multiple geographic and administrative domains. However, the allocation of the supplied services to jobs has been studied in less detail. Current resource management systems typically implement idiosyncratic cost functions for scheduling jobs. Those mechanisms, however, are central in nature. They work well if information about supply and demand is reported truthfully. Since Grid technology addresses resources sharing cross organizational frontiers, centrally controlled mechanisms suffer untruthful revelation of job related data.

Market mechanisms are known to attain fairly efficient allocations in situations where agents may reveal their private information about costs and valuations [Mi04]. In this context, several auction mechanisms and bargaining protocols have been proposed to allocate IT resources efficiently [e.g. BU01, Sc06]. However, none of the proposed mechanisms have yet made it into practice [La05]. One reason for this lies in the abstraction of the underlying trading objects. When referring to markets in the Grid, it is essential to consider the technical fundamentals and to understand what can really be traded and how. This requires a full understanding of the trading object and its characteristics. Oftentimes, this understanding is not fully integrated into the proposed mechanisms.

This paper attempts to diminish this gap between market mechanisms and technical specifications in service-oriented systems. We provide a thorough classification for potential trading objects and suitable formal descriptions in the Grid with regard to technical feasibilities. Our contribution is twofold: On the one hand, we provide a detailed technical and economical analysis and classification of different service types and suitable description languages for characterizing their properties. On the other hand, we give recommendations of potential market mechanisms for trading different types of services. Our goal is to provide a broadly diversified view that merges technical and economical perspectives on Grid services and to combine these aspects into an overall trading concept.

The paper is structured as follows: In Section 2, we introduce a novel classification schema for trading objects in a service market. Based upon this schema, Section 3 introduces and evaluates a set of formalisms to describe these trading objects. In Section 4, we review existing market mechanisms with regard to their applicability for trading different types of service. Finally, Section 5 concludes the paper.

## 2 Classification of Trading Objects

Trading objects in a Grid market implies trading rights to use certain services on different machines. Such services are heterogeneous in regard to their capabilities and their potential fields of application. Some of them may attract various agents while others are irrelevant for most users. Accordingly, the number of potential market participants depends on the type of service being traded. As the number of market participants has a profound impact on the design of a market mechanism, different types of services are analyzed with respect to their expected degree of supply and demand [Sc07].

Figure 1 depicts a three layered view on potential services in the Grid: *Standardized elementary services*, *standardized application services*, and *non-standardized application services* construct each layer respectively. Furthermore, the bottom line represents physical resources through which the service is provided. Physical resources are, however, not potential trading objects in the Grid, as they are virtualized by the middleware.

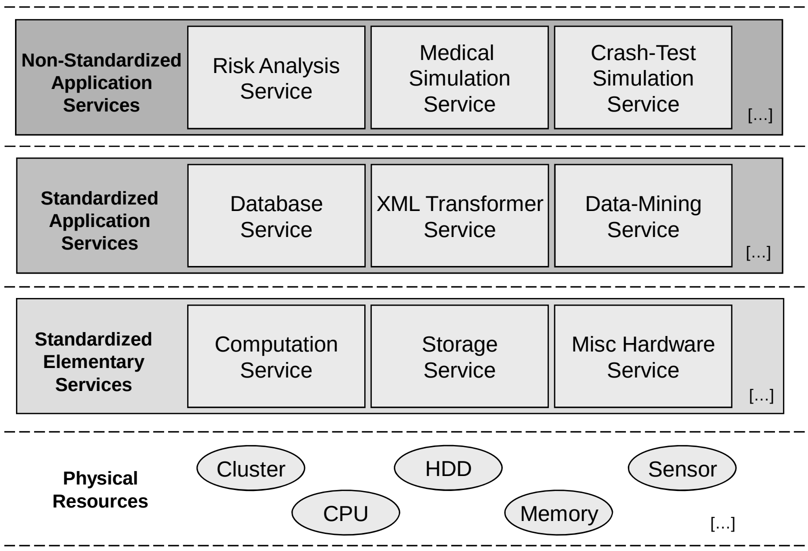


Figure 1: Layered view on different service types in the Grid

## 2.1 Standardized Elementary Services

The first layer comprises services that virtualize physical resources. This includes, for instance, a computational service that virtualizes a cluster. These resources are denoted as standardized elementary services. Although type and behavior of these services are mostly standardized, they have multiple attributes with varying characteristics. For instance, storage services may differ according to their capacity, access time and data throughput. These varying characteristics of the same type of resource, as well as the resource itself can be described by means of standardized description languages. As these services represent physical resources, they constitute elementary entities for a Grid that are required by various different users and applications.

## 2.2 Standardized Application Services

Application services with a broad scope of use are represented by the second layer. The input and output semantics of these so-called standardized application services are well-accepted and interpretable by a major part of Grid users. Exemplars might be database services and XML transformation services. Services in this layer are required for several different higher-level applications and, as a consequence, are utilized by a multitude of different users. Similar to elementary services, the provided quality of service levels for the same type of service may vary. For instance, a set of XML transformation services may vary from their offered response time; however, it is assumed that these characteristics can also be described in a standardized form.

### 2.3 Non-Standardized Application Services

Services represented by the third layer are non-standardized application services. Such services are only used for specific application areas such as a simulation service that is required for medical research. Their characteristics and capabilities often cannot be described by means of standardized and well-accepted description languages. It is not possible to describe all facets of important characteristics of a non-standardized application service by a set of attributes. The degree of a detailed description cannot be done comprehensively enough to capture all important aspects of such a service.

## 3 Formal Description for Trading Objects

Trading IT services by means of market mechanisms requires a precise specification of the object's characteristics in a standardized manner. In order to describe and exchange information on various trading objects, suitable formalisms have to be evaluated. While standardized elementary and application services can be described by well-established and widely-used formalism (e.g. WSDL, WS-BPEL), non-standardized services are too diverse to be characterized by a single flat set of attributes. We propose that the trading process of non-standardized services should be supported by rich underlying semantic information such as ontologies, taxonomies and constraints. Semantically enhanced formalisms may be useful to enrich description expressiveness to support efficient object allocation among market participants.

### 3.1 Standardized Elementary Services

Standardized elementary services build an encapsulating layer for accessing and managing physical resources. Thus, it is important not only to describe services on top of the resource layer but also to describe the attributes and properties of the underlying resources themselves. This section illustrates state-of-the-art description languages that can be used to represent standardized elementary services.

**Resource Specification Language (RSL):** RSL defines a specification concept for describing resource needs of submitted jobs [Cz98]. Attribute-value-pairs describe and control the behavior of one or more components in the resource management system. RSL is based on a string-based description syntax which is not standardized.

**Grid Laboratory for a Uniform Environment (GLUE):** GLUE [An05] defines an information model that is an abstract of the real world with focus on IT-infrastructure elements (e.g. servers, computers, databases). The core entities within a GLUE schema include a site concept, an abstraction of a service concept as well as computing and storage elements. In comparison to RSL, GLUE is based on an object-oriented concept which provides a higher expressiveness including simple semantic information such as hierarchy and taxonomies.

**Service Modeling Language (SML):** With the Service Modeling Language [Ar07], the SML consortium establishes a standard for modeling and exchanging system and resource models. Entity information covers aspects like configuration, deployment, monitoring, policy, capacity planning, target-operating range and service level agreements. SML consists of a profile of XML Schema and Schematron and extensions for typed inter-document references. Based on these constructs, it is possible to validate the correctness of models. Additionally, the Service Modeling Language Interchange Format (SML-IF) is a standardized exchange document which encapsulates models, model instances and rules. In contrast to RSL and GLUE, SML is a more generic approach for specifying models and constraints which do not have to focus on systems and resources necessarily. A central goal of SML is to provide a standardized interchange format in order to transfer models, rules and mode instances in a practical manner.

## 3.2 Standardized Application Services

Standardized application services provide a more complex functionality than elementary services. They often utilize compositions of services from the underlying layer in order to fulfill sophisticated tasks. Nevertheless, their attributes can be described in a standardized form. The following paragraphs outline means for describing standardized application services in a syntactic and semantic manner.

### 3.2.1 Syntactic Description Languages

Syntactic description languages focus on functional properties of service objects (e.g. operations). They provide standards to characterize basic service functionality.

**Web Service Description Language (WSDL):** WSDL [Ch01] can be used to describe network services. It is an abstract definition of an end-point-based communication to transport messages that contain document or procedure information. WSDL separates message descriptions from the actual transported data as well as port types which are abstract definitions of operations being performed. WSDL is suitable for describing standardized services, their operations and interfaces. Even more complex standardized services such as a data mining service can be specified on a basic level of detail.

**Business Process Execution Language (WS-BPEL):** WS-BPEL [JE06] is a standardized description language for composing Web services from a business perspective to fulfill certain tasks. It is a prescriptive formalism for modeling Web service orchestrations that focus on the business process view of one participant and not on a global scope. WS-BPEL concentrates on the execution layer of Web services and is based on WSDL specifications.

### 3.2.2 Semantic Description Languages

In addition to the previously outlined syntactic description languages, this paragraph gives a thorough overview over semantic enhanced standards to characterize service objects and highlights their relevance for service object trading. In most practical cases, pure syntactic descriptions are compact and computable for machines. Nevertheless, they lack of the capability to represent contextual and non-functional information on service properties, interfaces and operations (e.g. a service consumer wants to know what other services are involved in the interaction). In such cases, semantic description languages are capable of describing contextual and non-functional information in a high degree of detail.

**Web Service Description Language Semantics (WSDL-S):** WSDL-S defines extensions for WSDL that form semantic annotations. WSDL-S describes a general approach about how to enhance existing syntactical XML descriptions with semantic information. Important is the idea of the external domain model and the agnostic about its representation format, which is achieved through references. External domain models can be described through complex OWL ontologies representing comprehensive contextual information on the service, its properties and the preconditions and effects of its operations.

**Web Ontology Language Semantics (OWL-S):** OWL-S [Ma04] supplies Web service providers with a core set of markup language constructs for describing the properties and capabilities of their Web services in an unambiguous and computer-interpretable form. OWL-S markup of Web services facilitates the automation of Web service tasks including automated Web service discovery, execution, interoperation, composition and execution monitoring. OWL-S aims on extending best-practice standard like WSDL/SOAP, UDDI and BPEL but partly overlaps and describes redundant information.

### 3.3 Non-standardized Application Services

As discussed in Section 2, non-standardized application services are characterized by a high complexity and a vast usage of different resources. As a consequence, their characteristics and capabilities cannot be described by means of standardized, well-accepted and interpretable syntactic description languages.

When dealing with such complex services, it is fundamental to define a common language understanding for description and negotiation. Efficient knowledge exchange about a service is the basis for allocating diverse and heterogeneous trading objects. Hence, an ontology [Ga06] consisting of a terminology (domain vocabulary), fundamental concepts, their relationships to be defined in order to support the bargaining process. This specification of a shared conceptualization can be formally described by the OWL ontology language which facilitates logical inference and allows deriving of ontological information which has not been defined explicitly.

### 3.4 Discussion

Proposed languages for describing trading objects have been evaluated with respect to expressiveness, their precision (e.g. representation of non-functional properties including level of detail), syntactic description and serialization as well as taxonomy and systematics.

| Description Language | Service Classification | |
|---|---|---|
| | Standardized Services | Non-Standardized Services |
| RSL | Compact description but weak serialization (not XML conform) | - |
| GLUE | Detailed information can be represented leading to weak taxonomy and high complexity | - |
| SML | Detailed information can be represented leading to weak taxonomy and high complexity | - |
| WSDL | Sufficient integration of basic functional information. Non-functional information is missing | - |
| WS-BPEL | Description of service composition possible. Weak integration of non-functional attributes | - |
| WSDL-S | Sufficient integration of basic functional information. Non-functional information can be incorporated through semantic annotation | Additional service information through thorough semantic annotation (e.g. precondition/effect) |
| OWL-S | Representation of detailed service information possible but not based on any service description standard | Rich set of markup languages for describing properties and capabilities of service objects |

Table 1 Analysis of Description Languages

Table 1 shows that well-established description languages are more or less sufficient for describing standardized services such as storage, computational resources. According to the application scenario, the analysis provides detailed information on advantages and disadvantages with regard to expressiveness, serialization and systematics.

Nevertheless, syntactic description languages are not capable of providing contextual and non-functional information. Consequently, we propose the application of semantic enhancements for formalizing non-standardized service descriptions.

## 4 Market Mechanisms for Trading Grid Services

Having classified different service types and having specified languages for describing them, this section reviews market mechanisms that can be applied to trade these services efficiently. Due to the similar conditions of the layers comprising standardized elementary services and standardized application services, they are summarized by one layer for standardized services.

Markets as coordination mechanism for allocating Grid services can be established for both proposed types of services. However, the requirements upon each underlying market mechanism differ due to the different characteristics of the transaction objects. For standardized services, on the one hand, the number of potential providers and consumers is assumed to be high. The target resources are standardized transaction objects and, in some cases, even standard commodities. The number of different types of standardized services is limited, as only few services exist that are generic and fundamental enough to be utilized in various different fields of application. Due to their high degree of standardization, the provision and utilization of these services can both be automated. Non-standardized services of the same type are, on the other hand, characterized by a little demand. For instance, only few providers can offer highly specialized medical simulation services of the same type with the same functionality. As a result, the number of potential providers and consumers for such services is assumed to be low. In contrast to standardized services, various different types of non-standardized services exist; however, due to their specificity and their lack of standardized descriptiveness, they can hardly be discovered and invoked automatically.

| | **Market for trading** | |
|---|---|---|
| | Standardized Services | Non-Standardized Services |
| Number of providers and requesters | High | Low |
| Commodity type | Standardized | Unstandardized |
| Different types of resources | Low | High |
| Degree of automated usability | High | Low |

Table 2: Characterization of standardized and non-standardized services

The different characteristics of standardized and non-standardized services result in diametrical requirements upon a market for trading them. With respect to these differences, experiences gained from traditional procurement scenarios such as reported in [BMT04] can be transferred: Standardized services in the Grid can be compared to manufactured goods in procurement, such as rubbers and DVD players. For such commodities, literature emphasizes the benefits of auctions as adequate transaction mechanisms [Mi04]. Auctions, however, may not be appropriate for trading non-standardized services. These services, just as airplanes or buildings in procurement scenarios, are characterized by their complexity and their individual natures. A consumer of a non-standardized service may require several interaction steps with a supplier in order to clarify configurations and properties of the traded service. As such, communication and coordination interactions between the service counterparts are important requirements for trading non-standardized services. Such interaction capabilities are, however, not given by traditional auctions. In such cases, the use of bilateral negotiations may be superior to auctions, as negotiations facilitate communication and coordination among agents.

### 4.1 Trading Standardized Services

As stated above, the use of auction mechanisms is deemed promising for trading standardized services. In the following, we briefly review traditional and multi-dimensional auctions with respect to their applicability for trading standardized services.

There are different traditional auction formats that are implemented for trading Grid services: The *English auction*, as applied in [Bu01], is based on a public bidding process where the last bidder to state the highest bid wins the auction. The *Dutch auction* – applied in [FYN98] – counts an estimated price from a maximal value continuously down until a potential buyer stops the clock at a certain price he is willing to pay. In a *first-price sealed-bid auction* the highest bidder gets the object at his submitted value. Among others, [Ni00] apply such a format for trading CPU cycles in the Popcorn system. In a *second-best sealed-bid auction* or *Vickrey auction*, the highest bidder receives the good at the value submitted by the second highest bidder [Wa92]. The *continuous-double-auction (CDA)* and a *call market* as a periodic version are double-sided auctions. Multiple potential buyers and sellers offer their buying and selling values for an offered object. In a continuous-double-auction orders are preceded as they are submitted. If the buyers' price is equal or higher than the lowest selling price both offers are matched and the price clears and gets adapted. Among others, [JRG04] apply a CDA for trading Grid Services.

Traditional auction mechanisms can be effectively applied to allocate homogenous computational entities such as storage space or computation cycles. However, the mechanisms cannot be directly applied to trade all standardized services as they do not address service specific requirements. They neither support the allocation of service bundles (e.g. a bundle that consists of a storage service and a database service) nor support services with multiple attributes (e.g. a storage service that can be characterized by its size and its speed). For such services, the application of more complex auction mechanisms is superior. Depending on the preferences of the service consumer a composition of services might yield a higher overall utility then the sum of the values of the same unbundled services. In this case, the services should be coordinated by means of *combinatorial auctions*. Combinatorial auctions are multi-item auctions, where an agent can submit bids on multiple heterogeneous services as a bundle. As such, agents can express super-additive utility functions by means of expressing valuations for a bundle of services. A bundle consists of logical AND concatenated bids on a set of services. Such bids ensure that an agent is allocated to either all services of the bundle or to none of it.

Literature proposes different combinatorial mechanisms to coordinate service allocations: [SMT02] account for combinatorial bids by providing a tâtonnement process for allocating and pricing bundles of standardized Grid resources. However, the authors widely neglect time attributes for bundles and quality constraints for single resources. Hence, the use of such mechanisms in the Grid environment is considerably diminished. The introduction of time attributes redefines the Grid allocation problem as a scheduling problem. To account for time attributes, [We01] model single-sided auction protocols for allocating and scheduling resources under different time constraint considerations.

[PKE01] introduce the first combinatorial exchange as a single-shot sealed bid auction. As payment scheme, Vickrey discounts are approximated. The approach results in approximately efficient outcomes; however, the mechanism neither accounts for time nor for quality constraints. Counteractively, [Ba07] propose a family of combinatorial auctions for allocating Grid services. Although the mechanism accounts for quality and time attributes and enables the simultaneous trading of multiple buyers and sellers, there is no competition on the sellers' side as all orders are aggregated to one virtual order. Extending the concepts of combinatorial mechanisms, [Sc06] propose a multi-attribute combinatorial exchange called MACE. The auction is a combinatorial mechanism which supports bids on bundles, quality, and time attributes. With regard to the analysis of the authors, MACE qualifies for trading bundles of standardized services that have multiple attributes and timing constraints.

### 4.2 Trading Non-standardized Services

Non-standardized services cannot be formalized using standardized description languages. Thus, traditional auction formats are hardly applicable to this type of services. We think that the process of allocating non-standardized services involves negotiation protocols respectively bargaining mechanisms. For instance, Grid related systems such as CATNETS [Re05], OCEAN [Pa03] and Nimrod/G [Bu01] implement a variety of bargaining schemas. In the future, these mechanisms may be supported by the dedicated negotiation support systems [Ke04] or may be automated completely by means of software agents.

### 4.3 Discussion

The previous paragraphs evinced that a holistic market mechanism for trading all types of services may not exist. As a result, the different characteristics of potential markets for trading standardized and non-standardized services require individual and contrarily market mechanisms.

For standardized and homogenous services such as computing cycles or storage space, we propose the use of traditional auction formats such as the English auction or the CDA. Such mechanisms are easy to implement into an information system and evince a broad practical and theoretical background. If the services have multiple attributes such as the average response time of a database or the bit-rate of a music converter, the use of multi-attribute auctions is proposed. In case users require multiple services in a bundle, we propose the use of combinatorial auctions. This is necessary if a user wants to ensure the allocation of different services in a business workflow.

Finally, we propose the use of specific bargaining protocols for trading non-standardized services. As such types of services cannot be described by means of standardized description languages, the use of auction is impossible.

## 5 Conclusion

In this paper, we gave a thorough classification of different types of service objects in Grids. According to this classification, suitable description languages were evaluated with respect to trading and bargaining processes in Grid markets. Potential market mechanisms were illustrated and analyzed with focus on efficient allocation of service objects between market participants. We state that a technical and economical view on services and market mechanisms is necessary to understand how a basis for trading can be established and how the trading process itself can be designed efficiently. We analyzed the advantages and disadvantages of different languages and mechanisms that were proposed for service oriented systems. The classification schema and the corresponding evaluation of description languages and market mechanisms serve as decision support to specify and model efficient trading processes in the future.

Based on the recommendations of this paper, market mechanisms for different types of trading objects will be implemented in the *meet2trade* [We05] market engineering platform and evaluated based on different economical and technical metrics. Furthermore, this paper provides a thorough basis for future work in the field of complex services in Grid environments. Complex services require service infrastructures in order to be executed flawlessly. The interrelation of such service bundles requires standardized description formalisms on the one hand and more sophisticated semantic technologies on the other. Currently, a concept for complex service design is being developed in the context of the SORMA project [Ne07].

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