Chapter XXVI
Semantic Discovery of Services in Democratized Grids

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ABSTRACT

This chapter aims at discussing issues concerning the advertisement and semantic discovery of Web services in a democratized Grid environment: an environment in which users are agnostic of the low-level details for managing the services offered and requested. This type of environment poses new requirements, and thus, it affects the functionality of a service advertisement/discovery system. In the context of this aim, the chapter presents the motivation and the technologies developed towards a semantic information system in the Grid4All environment. The chapter emphasizes on bridging the gap between Semantic Web and conventional Web service technologies, supporting developers and ordinary users to perform resources’ and services’ manipulation tasks, towards a democratized Grid.

INTRODUCTION

Web services, as a distributed computation paradigm, raise a number of issues in order for their benefits to reach their potential. Semantic descriptions of Web services have emerged due to their prospective to support the automation of service discovery, invocation, composition and moni-
toring tasks by providing machine-exploitable meaningful declarative descriptions of service characteristics. Despite the benefits of semantic Web services, there is a gap between Semantic Web and conventional Web service technologies, which impedes the semantic manipulation of services’ registries, providing limitations for the adequate, flexible and seamless treatment of services. Ordinary Web users, software developers and service providers, as well as users of service registries must be supported to perform their tasks more effectively in such a machine-oriented (semantic) environment. This is particularly true for services or domains that change frequently: Stakeholders must be supported to perform their tasks in effective and adequate ways.

This chapter aims at presenting issues and solutions proposed for dealing with the problems of semantic web service advertisement, discovery and selection in a democratized grid environment: An environment that provides opportunities for (a) users that are agnostic of the low-level details required for managing services offered and requested, and for (b) service providers that need to make the best of their offered services. This type of environment poses new requirements, and thus, affects the functionality of a service advertisement/discovery system. In the context of these issues, the chapter presents specific technologies developed for realizing a Semantic Information System of a grid environment. The developed system supports the Grid4All approach for service discovery and selection in a democratized grid, in the context of the Grid4All European IST project.

The Grid4All project aims at developing a self-managed, autonomous, fault tolerant, and easy to use infrastructure that will enable ordinary users and small organizations such as schools and small/medium enterprises to share their computing resources. In this way, a ‘democratized’ grid is envisaged, which is accessible to organizations that lack the human and computation resources so as to participate in existing grids. In this context, Grid4All resources (traded in markets realized as specific types of services) and application-specific services are being advertised in the Grid4All Semantic Information System (G4A-SIS). The G4A-SIS provides a portal where semantically described grid services are advertised and discovered by (software and human) peers. Peers may pose to the G4A-SIS orders (i.e. requests and offers) concerning (a) specific resources that are being traded in markets, satisfying specific criteria/preferences/constraints concerning resources’ configuration, market and order-related properties, or (b) application-specific services’ profile specifications. These are further detailed in the sections that follow.

This chapter presents the technologies developed for the G4A-SIS to provide semantically-enriched functionalities for the resources/services’ advertisement and discovery tasks, towards a democratized grid environment. Special emphasis is given to the semantic specification of services’ profiles, supporting the effective discovery of advertised services.

The structure of the chapter is the following: in the next section, an overview of grid environments and web services is presented. Next, the Grid4All framework is presented, together with the need for an information system which promotes democratization. Next, the features of the Grid4All SIS are discussed, followed by a review of the state of the art in relevant approaches. The chapter ends with some conclusions.

**GRID ENVIRONMENTS AND WEB SERVICES**

**Grid Environments**

A grid provides the infrastructure for sharing and reusing entities by multiple users. These entities are referred to as ‘resources’. A grid is a collection of interconnected machines, sometimes referred to as “nodes,” “resources”, “members”,

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1. European IST project
“donors”, “clients”, “hosts”, or “engines”. They all contribute any combination of resources to the grid as a whole. There are various other kinds of resources such as computational, storage, network resources, code repositories and catalogs (Foster et al., 2001).

Grid computing may be seen as a step towards integrating various technologies and solutions that move us closer to the goal of making use of heterogeneous resources (exposed, marketed, offered and managed through services), with little or no knowledge of where these resources are located, or what are the underlying technologies. The grid is a distributed computing infrastructure, initially for high performance computing usage in the fields of science and engineering. Grid has emerged as a means of reusing existing infrastructure, that is, computers and storage media, either within, or through different organization boundaries or hosting environments (Foster et al., 2002). Grid systems are built mainly to facilitate a) application performance improvement, b) data storage and management, and c) enhanced access to different types of services (Krauter et al., 2002). Enhanced access to services refers mainly to the facilitation for collaborative and multimedia systems (Krauter et al., 2002; Bote-Lorenzo et al., 2003). Grids support the interoperation of applications in collaborative systems, thus, also enhancing human to human interaction, as in the case of Computer Supported Collaborative Work or Computer Supported Collaborative Learning systems where heterogeneous groupware or multi-conference applications interact (Bote-Lorenzo et al., 2003).

In multimedia systems, grid technologies facilitate enhanced QoS in multimedia applications with real-time constraints, such as videoconference applications (Krauter et al., 2002).

**Grid4All: Grid Democratization and Social Implications**

The Grid4All project aims at developing a grid infrastructure so as to enable domestic users, non-profit organizations such as schools and small/medium enterprises, to share their resources and to access massive grid resources when needed, envisioning a future in which access to resources is democratized, readily available, cooperative, and inexpensive. In other words, Grid4All envisions a “democratic” grid as a ubiquitous utility whereby domestic users, small organizations, and small-medium enterprises may draw on services on the Internet without having to individually invest and manage them. It aims to hide the complexity of grid-based systems, empowering individuals and organizations to create, provide access to, and use a variety of services, anywhere, anytime, in a transparent and cost-effective way, realising the vision of a knowledge-based and ubiquitous utility. Such a transparency is achieved through technologies based on new paradigms concerning self-managed systems, market-orientation, and the Semantic Web.

On the economic front, the community-inspired scenarios motivating Grid4All can create new kinds of micro-economic opportunities: Providing incentives to resource/service owners to share their resources/services raises the possibility to create and generate local, dynamic micro-economies where local enterprises and providers can trade resources/services with the local residents in return for micro-payments. These payments are intended to compensate the overhead of maintenance, administration and complexity of usage space weighs on small enterprises who may offer some of their ICT resources on a service-oriented basis. Grid4All tackles this issue through technical components for resources/services’ discovery, brokering and trading.

Small organizations such as schools, community centres and individuals at their homes may benefit from the Grid4All infrastructure by means of discovering, negotiating and accessing services (resource trading services, i.e. markets, and application-specific services) at times of accrued local needs with respect to their specific needs, preferences and budget-related constraints.
Grid4All Economy and Market Model

Grid4All peers participate in either non-profit or for-profit basis in order to acquire, provide or share resources and services. For supporting the for-profit case, Grid4All proposes a market model and a specific market-oriented architecture.

In a market-based environment as envisaged by the Grid4All project, grid resources and services can be made available through peer-initiated markets in a distributed manner. Grid4All adopts a distributed market model where (resource) consumers and providers negotiate on certain traded entities in auctions initiated by providers, consumers or by third party entities. The market place can be considered to be populated by multiple, simultaneous and independently executing trading instances (markets).

Traded goods in grid markets are being allocated to peers based on the supply and demand law. This architecture reduces the computational complexity of centralized auctions that accrues with the number of offers and bids and ensures scalability. In such a distributed market-oriented environment, the discovery of markets with efficiency, precision and scalability is a challenging necessity.

Services Within Grid4All

In order to facilitate uniform access to grid resources, especially in heterogeneous environments, grids exploit service oriented architecture (SOA) approaches (Papazoglou & Georgakopoulos, 2003). That is, each resource in a grid is exposed by a service, thus, facilitating location transparency, uniform semantics and platform independence, as well as virtualization, that is, “encapsulation of various implementations behind a common interface” (Foster et al., 2002). OGSA, a prominent architecture for grid systems (Foster et al., 2002), aims at exposing resources, both computational and storage, through web services. Web services are described by their WSDL descriptions, while other specifications have been proposed so as to capture the stateful nature of grid services, such as WSRF.

Grid4All, following the generic trend of grid computing, has adopted the Web Services standards to align with existing languages, programming models, tools, and technology directions in Web services and systems management.

Concluding the above, the following are types of discoverable services within Grid4All:

- Market services (i.e. services for trading resources)
- Services that expose computational and storage resources
- Application-specific services

The service discovery component that has been developed within Grid4All aims at the discovery of the above kinds of services. In its current state, the Grid4All Semantic Information System (G4A-SIS) endorses semantic web technologies in order to facilitate the advertisement and querying of available markets and application-specific services.

THE GRID4ALL SEMANTIC INFORMATION SYSTEM (G4A-SIS)

Overall Description of G4A-SIS

G4A-SIS provides a matching and ranking service for peers willing to offer or request resources and services.

Concerning resources, G4A-SIS aims to discover market services (trading instances) that trade resources satisfying specific requirements. Towards this target G4A-SIS exploits resources’ offers and requests (detailed in the sections that follow), in conjunction to resources’ characteristics and market-related properties, to satisfy peers’ intentions and preferences. Resource retrieval in this context extends the notion of resource
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matchmaking to the process of discovering those markets (trading instances), each with its own auction mechanism, which trade resources matching the requests of buyers and the offers of sellers. To satisfy the requirements of resource retrieval in this context, a specific ontology (Grid4All ontology) has been developed which is being exploited by the Semantic Information System (Vouros et al., in press). The ontology describes resources, markets, offers and requests, peers and their relations in a formal way.

As far as application-services are concerned, to support the democratization of grid, G4A-SIS supports the automatic semantic annotation of these services, and thus their automatic advertisement in the semantic registry, as well as their retrieval via semantic matchmaking techniques. This is important in the deployment of G4A-SIS in the democratic grid, since it alleviates users from possessing detailed knowledge on the semantic specifications of services involved, while facilitating adaptation in evolving ontologies and changing service specifications.

It must be emphasized that although markets are a specific type of services and are been treated in a semantic way (by exploiting the Grid4All ontology), they are treated differently from application-specific services. This shall be made clear in the next sections.

G4A-SIS Workflow

The Semantic Information System (G4A-SIS) provides a matching and selection service for peers to offer or request resources and services within grid environments.

The G4A-SIS may be queried by software agents, as well as by human users to select advertised markets (trading resources) and services: Matchmaking happens through different criteria concerning markets and application-specific services. For application services, matchmaking is based on services’ profiles, while for markets this is done by exploiting resources’ configuration, markets’ characteristics and order-related attributes, as these are being specified in the Grid4All ontology. However, in both cases, query results are ranked according to resources/services matching characteristics and providers’/consumers’ features.

The overall workflow of the G4A-SIS is illustrated in Figure 1. The G4A-SIS contains a regis-

Figure 1. G4A-SIS workflow
try in which market and application services are advertised by the agents. Application services are advertised by a specific process named WSDL annotation. The discovery of services and resources is performed by submitting queries for market and application services. Services that fulfill querying criteria are retrieved by means of a matchmaking process involving semantic technologies, while the ranking of results is performed by a selection process. The matchmaking and selection features are discussed in next section.

**Functionality of the G4A-SIS**

As mentioned earlier, the main functionalities of the G4A-SIS are the discovery of market services (trading instances), and the discovery of application-specific services (e.g. of a collaboration tool with specific data semantics). Despite the fact that markets that trade resources (resource markets) are services themselves, as shown in Figure 1 and pointed out, these two types of services are handled by G4A-SIS in different ways.

**Market Advertisement**

The purpose of market advertisement is the insertion into the G4A-SIS registry of descriptions of markets that are related to offers or requests made by providers or consumers, correspondingly. Both offers and requests are specific kinds of *orders*. Descriptions of orders (offers and requests) contain information about the entities that are been traded by the associated markets (i.e. resources’ configuration), the associated markets, the participants (providers and prospective consumers), as well as attributes of the orders themselves. Such descriptions are formed as classes and instances of the Grid4All ontology classes, stored in OWL format. Markets can be either forward or reverse.

Concerning forward markets, orders concern resources offered to potential customers. Providers are able to advertise a list of offerings combined via XOR or AND connectives, specifying either alternative service/resource configurations at different prices, availability times etc, or conjunctive offers, as a bundle offer. Descriptions of available tradable resources as well as of the related markets are aggregated to *Offers*.

Consumers, acting as provisional buyers, initiate reverse markets in which they call for resources of intended characteristics, thus forming requests. Descriptions of intended resource characteristics associated with reverse markets are aggregated to *Requests*. Similarly to offers, requests may concern a single trading resource, or a “complex” one, concerning a bundle of resources: Multiple, alternative (respectively, conjunctive) requests may be connected using an XOR (respectively, AND) connective.

Summarizing the above:

- A Request describes the resource needs of a consumer (quantity of requested resources and time intervals of their allocation) and the price the consumer is willing to pay for those resources within a specific Market;
- An Offer specifies the exact resources (quantity of offered resources) that a provider trades in specific time intervals and prices: This is in contrast to the specification of requested resources, where the consumers may request a *class* of resources. Offers specify the exact individual resources that providers sell.

Beyond the above information, market orders, that is, offers and requests contain the following information:

- **Market related information**: The description of a market where the resource/service is going to be traded. This includes location of market, start and closing time of market.
- **Offer/request related information**: The description of pricing policy (type of related market auction), initial price (minimum price...
for a forward auction and maximum for a reverse auction).

- **Contact information:** Information about the provider or consumer.

Orders deal with two types of grid resources: Computational and Storage resources. Not all resources are tradable. For instance, one may not trade a CPU or a Hard Disk, as such. Tradable resources include Compute Nodes and Clusters.

- A Compute Node is a type of Composite Resource that comprises exactly one Computational Resource and any number of Storage Resources.
- A Cluster is an Aggregated Resource comprising a set of Compute Nodes.

A market is to be advertised directly by its initiator, either provider or consumer, or through the market factory which instantiates this market. The advertisement of markets is supported by an appropriate API (to be used by software agents) as well as by a web-based user interface (to be used by humans). No authoring of formal descriptions of the input information is required from the peers in order to make any advertisement.

**Market Discovery**

The aim of the market query feature of the G4A-SIS is to provide to prospective providers/consumers an ordered list of available markets, already been advertised to G4A-SIS, that satisfy certain criteria concerning their own characteristics, as well as the characteristics of the traded goods: Performance and QoS characteristics of resources, the configuration of resources, pricing and order-related criteria.

Specifically, peers may query the G4A-SIS for orders (i.e. requests and offers) that match certain attributes and criteria, locating orders that are related to matching resources (i.e. resources satisfying the ordered configuration requirements), traded in forthcoming (initiated but not yet started), or ongoing markets. As it will be explained, the results of queries are ranked according to the preferences and intentions of providers and consumers, as well as according to the characteristics of resources and markets.

**Application-Specific Service Discovery**

Besides markets, the G4A-SIS provides application-specific services discovery functionalities. Application services are considered to be available for free, that is, they are not traded through markets (although G4A-SIS can support traded services as well). Currently, we have considered that services’ semantic descriptions of profiles suffice for their semantic discovery. Therefore, service profile descriptions are being registered in the Semantic Information System as OWL-S specifications. Queries for services are submitted to the G4A-SIS as lists of input/output types. We make the assumption that the I/O types in a submitted OWL-S profile document are already known, i.e. they are references to existent ontology classes/individuals.

The matching of service advertisements to a submitted service query is divided in two main stages: a) matching of inputs, and b) matching of outputs. For the matching of inputs and outputs, the direction of the subsumption relation is important for (a) the input types to ensure proper execution of the service and for (b) the output types to fulfil the demands of the service requester. The types of service matching supported by G4A-SIS are:

- **Exact match:** For every input type of the advertised service, one equivalent input type of the required service is found. Also, for each output type of the required service one equivalent output type of the advertised service is found. The service I/O signature
perfectly matches with the request with respect to their formal semantics.

- **“Subsumes” match**: For each input type of the advertised service exactly one input type of the required service has been found, which is at least subsumed by the input type of the advertised service. This means that the advertised service might be invoked with a more specific input than expected. The output types of the required service subsume the output types of the advertised service or are equivalent to them. This means that the required service might receive a more specific output type than expected. Additionally, for all output types of the required service a successfully matching counterpart of the advertised service is identified.

- **Fail**: Service S fails to match with request R in any of the ways described above. This means that one of the following holds: a) at least one input type of the advertised service has not been successfully matched with one input type of the advertised service, and so the service cannot be executed properly, or b) at least one output of the required service has not successfully been matched with an input of the advertised service.

### Application-Specific Service Advertisement

An agent offering a service, that is, a provider, submits a service description in WSDL, and a respective annotation document named External Annotation File (EAF). The EAF is an XML document that provides entries (“slots”) for the (semantic) annotation of WSDL elements. The EAF annotations are aligned with the WSDL specifications via XPATH expressions. EAF provides elements for “comments”, “description”, as well as “type reference” to ontology classes, for each of the WSDL elements. Each “type reference” specification maps each WSDL input/output part element to an ontology class, and hence, it semantically annotates the WSDL element. Having the mappings between service I/O types and concepts in OWL ontologies, an OWL-S profile specification is automatically generated and inserted in the G4A-SIS registry.

Specifically, during service advertisement, the annotation document of each service is prepared by using the annotation tool described in the next paragraph.

### WSDL Annotation Tool

WSDL annotation is an important part of the overall advertisement and thus, matchmaking and selection process, since its purpose is to explicate the data semantics of WSDL specifications, generating the semantic description of services’ signatures (profiles). Annotation can be performed either in interaction with humans or automatically, given that sufficient descriptions of WSDL parts to be annotated are provided. Performed interactively, humans provide the mappings between WSDL Input/Output (I/O) messages’ part names (WSDL input/output parts) and ontology classes (we call this mapping process semantic annotation). Done automatically, we have devised a mapping mechanism that computes mappings between WSDL input/output parts and OWL classes: To support the automatic semantic annotation of WSDL specifications, humans have to provide descriptions and comments concerning the intended meaning/use of input/output parts and of the types used (in contrast to semantic annotation, we call this process text annotation). These annotations may also be fetched by documentation and comments associated with the service code.

This Annotation Tool (WSDL-AT) supports a) the manual text annotation of WSDL elements with comments and descriptions in natural language, b) the automatic semantic annotation of WSDL elements with references to classes of domain ontologies, and c) the validation of semantic annotations.
produced. The results of (semantic) annotation are encoded in the annotation file (EAF).

Creating and authoring the EAFs for WSDL files. Specifically, concerning this task, by using the WSDL-AT, users are able to create a new EAF when the annotation process of a WSDL file starts. However, if an EAF already exists, the WSDL-AT imports and shows the existing annotations, providing appropriate editing facilities to the users. During the annotation procedure, the WSDL-AT provides a set of ontologies from various application domains, among which the user may choose the “appropriate” ontology for performing the semantic annotation. The same ontology shall be used for the validation of the semantic annotation of the WSDL elements.

Providing mappings of WSDL I/O parts to the classes of a given ontology. Concerning this second task, WSDL-AT initiates a WSDL-to-OWL mapping process. Having the textual an-

Figure 2. “Proposed Annotations” tab and domain ontology hierarchy

Figure 3. Mapping WSDL elements and ontology classes
notations (provided in natural language within the “descriptions” and “comments” elements of EAF) of WSDL input/output part elements, WSDL-AT automatically computes the OWL classes (from the domain ontology chosen) that are being assessed to correspond to the WSDL input/output part elements (i.e. the semantic annotations of WSDL input/output part elements). This computation is performed using algorithms from the ontology alignment paradigm. The assessed ontology classes for each WSDL input/output part element are returned in a ranked list, as illustrated in Figure 2; the higher position in this list implies a stronger matching proposition between the WSDL part element and an ontology class. Human annotators are able to inspect the domain ontology and the suggested mappings produced by WSDL-AT. However, as Figure 3 shows, the human annotator is able to change the semantic annotation of a WSDL part element by selecting an alternative ontology class (from the domain ontology hierarchy).

WSDL-AT is a platform-independent stand-alone application, with a graphical user interface (GUI).

Application-Specific Services’ Querying

Prospective clients submit queries to discover services that are already been advertised in the G4A-SIS registry. An application-specific service query is specified by a list of input and output types for the services that the client intends to invoke. These types are OWL classes defined in domain ontologies that are stored in the G4A-SIS. The output of a service query is a ranked list of endpoint references of services, which match the query criteria. A match exists between an advertised and a required service if their input and output types satisfy the conditions described as exact or “subsumes” matching, described previously. By using the endpoint references of the matching services, a prospective client can invoke any of the discovered services.

Selection Module

The Selection Module (SM) of the G4A-SIS is used for the ranking and selection of services and markets. SM allows ranking and narrowing down the relevant peers’ (buyers or sellers) list found by the Matchmaking Service (i.e. those that may provide the ordered service). The SM module

Figure 4. The web user interface of the G4A-SIS
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ranks (or narrows down) the list of these peers according to (i) the preferences that providers/consumers have towards consumers/providers, respectively (regarding providers’ reputation, for example), (ii) the preferences that providers/consumers have towards queries (regarding which data or service is concerned by the query), and (iii) the query load of providers/consumers. With this aim, it is assumed that consumers and providers declare at any time their preferences to G4A-SIS so as to get the most preferred results. Any peer can define default preferences for those peers it does not know.

Overall, SM aims at satisfying buyers and sellers so that they have the same chances of doing business and getting interesting resources or services in the long-run. Satisfaction, in our context means, how well preferences are met by queries a seller gets and by resources/services a buyer gets. More details and validation results on selection mechanism are provided in (Quiané-Ruiz et al., 2007).

G4A-SIS Implementation

The G4A-SIS exposes its functionality as a specialized portal. It provides a web-based interface as well as an API in order to be accessed by human users and software agents. In both cases, no knowledge of the internal semantic representation of resources and services is required. With regards to human users, appropriate web forms for the submission of both requests and offers are provided. These forms are automatically generated from the underlying Grid4All ontology. Furthermore, market orders’ matchmaking is performed internally by a) the automatic classification of individual orders with the computation of their inferred types (by means of the Pellet reasoner7), and by generated b) SPARQL8 queries for filtering the matching individuals according to market-related properties and orders’ constraints. Both functionalities are transparent to the human user, as well to the software agent who performs advertisements and queries. A snapshot of the G4A-SIS user interface is shown in Figure 4.

STATE OF THE ART

Semantic Information Systems for the Grid

The following paragraphs describe systems and software frameworks that provide matching of resources and services in grid environments. The provided descriptions focus on the requirements and features provided by these systems and frameworks as well as on the use of semantic technologies in order to meet these requirements. These approaches can be classified in two categories. The first category contains systems that facilitate the discovery of services in a domain-independent way, while the second category contains systems that support the discovery of services in particular application domains such as e-learning and biomedicine.

Harth et al. (2004) present a system for matching resources to requests (applications) of users and agents in a grid environment. The OMMS (Ontology-based Matchmaker System) adopts an extensible approach for performing grid resource selection that uses separate ontologies to describe resources and job requests. Thus, the matching between job requests and available resources is performed in a semantic rather than in syntactical level. Matched resources are ranked according to user preference using a ranking function, which is an arithmetic expression expressed in terms of resource properties. Ludwig & Reyhiani (2006) define a matchmaking framework for semantic service discovery in grid environments and a portal which implements this framework. The aim of the framework is to provide matches between applications and available services. Semantic matchmaking is based on reasoning using structured information about available services and applications, rather than mere syntactic match-
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ing based on service/application attribute name comparison. The framework fulfills a number of requirements such as high degree of flexibility and expressiveness, supporting "subsumes" service matching type, compliance with existing grid technologies and capability of lookup and invocation of matched services. The proposed matchmaking mechanism is based on a shared ontology and is defined in three stages: Context selection, where the appropriate context ontology is chosen, semantic selection, where requests are matched to services according to the metadata descriptions of services, and registry selection, where services are looked up in a UDDI registry. Service descriptions are defined in the DAML+OIL ontology language. A service discovery portal implements the framework, supporting the advertising, viewing and searching of services. The framework provides a similarity metric for avoiding the exploitation of the matching mechanism by too generic advertisements or requests that attempt to maximize the likelihood of matching and for facilitating ranking of selected services.

In (Paolucci et al., 2002) a solution for web service advertisement and matching based on a semantic description of web services is described. This description consists of a combination of DAML-S and UDDI standards. The requirements for matching services are flexibility, minimization of false positive and negative matches, and efficiency. DAML-S descriptions are used for formalizing the functionality of the advertised web services using service profiles, while UDDI is used for syntactic keyword-based matching. An implementation of a DAML-S/UDDI Matchmaker is provided. An algorithm for matching of DAML-S descriptions of services is proposed and implemented.

A number of systems have also been developed for the discovery of domain-specific grid resources and services based on semantic descriptions for specific application domains such as Computer-supported Collaborative Learning (Vega-Gorhojo et al., 2006), Bioinformatics (Wroe et al., 2003) and Meteorology (Ren et al., 2006; Kaijun et al., 2006). These systems are based on Semantic Web formalisms for the annotation of resources and services such as OWL-S and DAML+OIL. The ontologies on which they are based are domain specific, that is, they define concepts that have a specific meaning in the specific context of the application, and thus support refined queries, meaningful for experts in the specific field.

Ontologies for Trading Resource/Services in Grid E-Marketplaces

In this section, approaches for the allocation of resources within grid computing environments based on economic models that provide algorithms/policies and tools for effective and dynamic resource sharing/allocation are described. Like Grid4All, in these cases, resources are traded within markets following price-based models (as opposed to bartering/exchange-based models), based on demand, supply, value, and the wealth of economic systems. Furthermore, end users may want to negotiate prices based on demand, value, preferences, and available budget (Buyya et al., 2005; Buyya et al., 2001).

Traditional resource descriptions’ matchmaking approaches are mostly based on syntax, and/or attributes of resource descriptions (Veit et al., 2001). These approaches are difficult to be extended in order to handle partial or incomplete specifications of market orders (resources’ offers/requests), or to support flexible retrieval processes based on the semantics of the specifications of peers’, markets’ and resources’ characteristics. Recent approaches (e.g. Colucci et al., 2005; Li & Horrocks, 2003; Sycara et al., 2003) suggest adopting semantic service/resource descriptions for matchmaking, by means of ontologies, featuring logic-based representation languages. However, these approaches propose the use of centralized matching components paying little
or no attention to market-related properties and peers’ features.

Lamparter & Schnizler (2006) present an architecture of an ontology-driven market for trading Semantic Web Services. They report on an auction schema which is enriched by a set of components enabling semantics-based matching as well as price-based allocations. The key issue of this work is the merging of classical auction algorithms with the semantic matching capabilities. They propose a communication language which defines how orders (requests and offers) and agreements concerning web services can be formalized. This work contributes towards the grid economy dealing with a single type of auctions concerning Semantic Web Services: It does not deal with multiple types of markets and their distinguishing features. Preferences of providers and consumers are not taken into account during the matchmaking process.

Closely to our approach, the work reported in (Ragone et al., 2007), aims to semantic matchmaking in P2P e-marketplaces. This approach mixes in a formal and principled way the semantic expressiveness of DLR-Lite logic programs, fuzzy logic and utility theory to find the most promising partners in a peer-to-peer e-marketplace. Following the economical model to negotiation, this approach considers peers’ preferences and utilities in the matchmaking process. A major issue concerns the modelling of logical specifications as soft-constraints (requirements and preferences on the peers’ orders) using fuzzy logic. Focusing on knowledge representation, the framework proposed offers an alternative to our work on formalizing the retrieval of resources in a grid-related market-oriented environment: However the proposed framework is under implementation. Concerning the conceptualization proposed, although the matchmaking approach is market-oriented, it seems that the focus, as far as markets are concerned, is only on pricing (value of goods), i.e. on the process of retrieving resources based on price negotiations between peers. As a consequence, there is lack of information concerning market and order related properties that a peer may consider in order to trade a resource.

Concluding the above, to the best of our knowledge, recent approaches provide effective semantic matchmaking services for discovering and selecting peers that satisfy requests/offers in an e-marketplace. However, there is a lack of a formal conceptualization of all the types of elements involved in a grid market-oriented computing environment: a) The types and characteristics of the resources, b) the properties and constraints related to the specific offers and requests, c) the specific properties of the markets to which the specific orders are placed, and d) the preferences and characteristics of the providers and consumers that participate in these markets. In the approach presented in this chapter we have dealt with the first three types of elements.

CONCLUSION

The Grid4All project aims at developing a self-managed, autonomous, fault tolerant, and easy to use infrastructure that will enable ordinary users and small organisations such as schools and small/medium enterprises to share their computing resources. In this way, a ‘democratized’ grid is envisaged, which is accessible to organizations that lack the human and computation resources so as to participate in existing grids.

Towards this target, as far as resources and services are concerned, the Grid4All project adopts a market-oriented model, so as to give opportunities to resources’ and services’ providers and consumers to satisfy their needs at the lowest cost. In such a setting, where multiple markets operate and multiple application-specific services are being offered, it is a necessity for peers to manipulate effectively three types of services identified: (a) market services (i.e. trading instances), (b)
services exposing resources, and (c) application specific services. Manipulation of these services entails at least their advertisement and effective discovery. Furthermore, peers must be facilitated to the manipulation of services, since ordinary users and small/medium organizations, which are the main stakeholders of the Grid4All framework, are agnostic of the low-level details required for managing services offered and requested. Also, service providers need to make the best of their offered services. This type of environment poses new requirements, and thus, affects the functionality of a service advertisement/discovery system. In the context of these issues, the chapter presents specific technologies developed for realizing a Semantic Information System of a grid environment. The developed system supports the Grid4All approach for service discovery and selection in a democratized grid.

In this context, Grid4All resources (traded in markets realized as specific types of services) and application-specific services are being advertised in the Grid4All Semantic Information System (G4A-SIS). The G4A-SIS provides a portal where semantically described grid services are advertised and discovered by (software and human) peers. Peers may pose to the G4A-SIS orders (i.e. requests and offers) concerning (a) specific resources that are being traded in markets, satisfying specific criteria/preferences/constraints concerning resources’ configuration, market and order-related properties, or (b) application-specific services’ profile specifications.

This chapter presented the technologies developed for the G4A-SIS to provide semantically-enriched functionalities for the resources/services’ advertisement and discovery tasks, towards a democratized grid environment. Special emphasis is given to the semantic specification of services’ profiles, supporting the effective discovery of advertised services.

REFERENCES


**KEY TERMS**

**Web Service Discovery:** The process of retrieving specific service information from a service registry by submitting appropriate queries.
Web Service Annotation: The process of attaching metadata to a web service. These metadata typically carry information about service-related data types and execution semantics.

Services’ Semantic Information System: A system for the advertisement and discovery of web services and markets in the grid environments based on ontology descriptions.

Semantic Matchmaking of Services: The identification of a set of semantic descriptions of markets and services that fulfill the criteria imposed by a query for market/service discovery.

Services’ Selection: The process of ranking and narrowing down the list of market/query results within a services’ semantic information system based on user preferences.

Grid Resources: Computation and storage facilities to be discovered and used in a grid environment. These facilities are accessed as web services.

Market Request: In a Grid4All market, a request is a description of the resource needs of a consumer, together with the price the consumer is willing to pay for those resources within a specific market, as well as request-specific properties, such as the time interval that resources need to be allocated.

Market Offer: In a Grid4All market, an offer is an exact description of the resources that a provider trades in specific time intervals and price.

ENDNOTES

1 The authors acknowledge the European Commission for funding Grid4All under grant number FP6, project IST-Grid4All-2006-034567.
2 http://www.w3.org/TR/wsdl
3 http://www.globus.org/wsrf/
4 http://www.w3.org/TR/owl-ref/
5 http://www.daml.org/services/owl-s/1.0/
6 http://www.w3.org/TR/xpath
7 http://pellet.owldl.com/
8 http://www.w3.org/TR/rdf-sparql-query/