Grid Services Mediation

M. Younas, K-M. Chao, R. Anane, S. Y. Yan, P. J. Lovett, A. N. Godwin
Distributed Systems and Modelling Research Group
School of MIS, Coventry University, Coventry, UK
{m.younas, k.chao, r.anane, s.yan, p.lovett, n.godwin}@coventry.ac.uk

Abstract

Grid services are software components that provide seamless access to a variety of grid resources such as computational resources and data sources. We present a new multi-agent framework which aims to ensure effective mediation of grid services. The framework comprises different services including search and discovery, planning and coordination, and service reliability and security. The main objectives of the framework are to dynamically discover grid services, devise effective planning and coordination strategies for the discovered services, and securely and reliably utilise those services.

1. Introduction

Grid computing enables seamless interoperation of heterogeneous systems in order to facilitate resource sharing, such as the sharing of CPU cycles, disk storage, and software processes. Grid computing is used for a multitude of applications ranging from molecular modelling through neuroscience to NASA information management. Aspects of grid computing that are currently the subject of research include the Globus Alliance research project (www.globus.org) which is investigating resource management, data management and access, information services, and security aspects of grid computing. The European data grid (http://eu-datagrid.web.cern.ch/eu-datagrid/) project is exploring the area of large-scale databases so as to enable data sharing among distributed scientific communities. In addition to these, a large number of academic and industrial groups are actively involved in grid computing research (see Grid Computing Info Centre (http://www.gridcomputing.com/).

This paper details an investigation into grid services which are built on the concepts and technologies of grid computing and web services. Grid services are software components that provide seamless access to a variety of grid resources such as computational resources and data sources. Grid services also provide useful behaviour such that they can be used by other software applications [4]. OGSA provides a platform GT3 (Globus Toolkit 3) that allows a higher-level mechanism to incorporate grid services into applications [4, 15]. Component grid services can be combined when no single grid service can satisfy the functionality required by a grid application. In this case, an option should be provided to compose existing grid services so as to fulfil the application's requirements.

In this paper we propose a new multi-agent framework in order to ensure effective mediation of grid services — to dynamically discover grid services, devise effective planning and coordination for the discovered services, and to securely and reliably utilise those services. The proposed framework presents preliminary work as a part of our ongoing research project on grid services mediation. The framework is diagrammatically shown in Figure 1. It comprises the following phases:

Service discovery: This phase concerns the dynamic discovery of grid services. It incorporates fuzzy logic and an ontology mechanism to effectively discover grid services that suit the requirements of the grid application. Grid service providers publish their services using different service directories such as UDDI, Globus Metacomputing Directory Service (MDS), and Grid Market Directory (GMD) [6]. Service consumers discover services through these directories.

Service planning and coordination: This phase deals with the planning and coordination of the grid services. Based on multi-agents planning and coordination mechanisms, this phase devises effective plans to select and coordinate appropriate services from the discovered grid services so that they meet the application's requirements.

Service reliability and security: This phase ensures the secure and reliable execution of grid services using transaction management (TM) technology and security protocols.

The remainder of the paper is organised as follows: Section 2 reviews current work on grid services and identifies related issues. The proposed framework is

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presented in Section 3. Section 4 concludes the paper and illustrates future work.

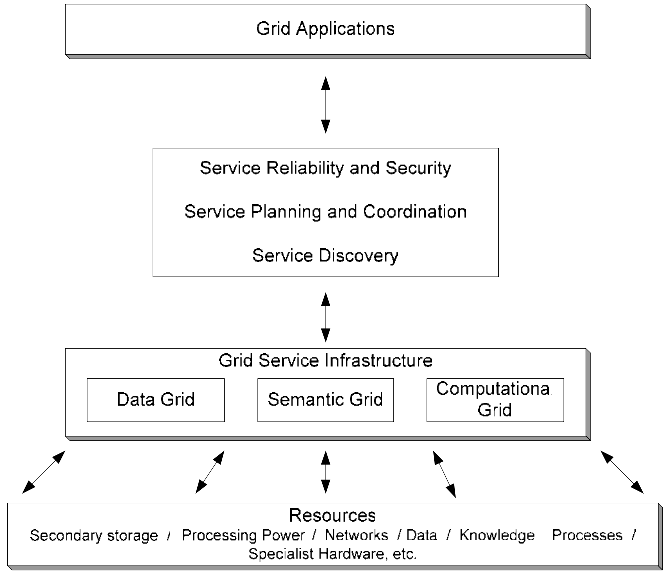

Figure 1: Proposed Grid Framework

2. Analysis of the related work

This section reviews current research on grid services within the context of grid services discovery, coordination, transactions and security.

Grid services discovery: Given the open and widely distributed nature of the grid, service discovery is an important issue. Services can be discovered using centralised directories or other search tools. Globus defines a Metacomputing Directory Service (MDS) for publishing and discovering grid services. MDS provides information on published grid services. Another directory service is the UDDI which is used for online registry, publishing and discovery of Web services offered by different service providers. Grid Market Directory (GMD) [6] is also developed for grid services discovery and publishing. Directories are useful in terms of providing a single point of access to grid services. However, they are prone to failures and poor scalability.

In addition to the above, information retrieval (IR) techniques are also applied to grid information search. For instance, the grid information retrieval (GIR) group [5] aims to apply information retrieval techniques to grid computing. It also applies grid tools and techniques to further enhance the process of information retrieval. IR techniques are useful as they can potentially search a large number of grid services which are distributed across a network of service providers. However, current IR techniques seem to be inappropriate for the search for and discovery of grid services due to the fact that these techniques are mainly based on a keyword search.

Grid service coordination: Grid resources have unpredictable availability and lifespan given the dynamic and uncontrollable nature of grid computing. Various mechanisms have been developed for automating the coordination of grid resources. The OGSI specification (http://www.gridforum.org/) is an attempt to provide an environment wherein grid services can become more manageable in large and complex distributed applications. The current specification of OGSI does not provide a universal co-ordination mechanism for orchestrating grid services. In addition, ontological tools are used to coordinate grid services. Ontological tools provide grid services with clear meaning and descriptions. For instance, OWL-S [3] is the current standard for defining an ontology for grid (or Web) services so as to provide richer service description.

Grid transactions and security*:* Transaction management (TM) technology provides a facility whereby several operations can be treated as a single logical unit of work performed as a part of one application [11, 12]. TM technology has the potential to provide different applications with correct, consistent, and reliable execution. The TM-RG grid forum [8] is investigating the application of TM technology in the grid environment. It defines different use cases of grid applications that can benefit from TM technology. These include long running computations on the grid, resource management on the grid, credit verification, and so on. The work in [7] uses formal methods techniques in order to formalise transaction management in grid computing. This work is still in progress. One of the findings of our investigation is that the Web services TM technology can be applied to grid services. These include, for example, business transaction framework (BTF) [10], WS-Transactions defined by IBM and Microsoft [11], and business transaction protocol (BTP) defined by OASIS [9]. Papazoglou [10] proposes a business transaction framework (BTF) for Web services and outlines requirements and characteristics of business transactions. The WS-Transactions approach [11] was developed by IBM and Microsoft in order to manage effectively Web transactions in business activities. WS-Transactions and BTF aim to define a framework for providing transactional coordination of the participants of services offered by multiple autonomous businesses. Further, OASIS [9] defines a protocol for Web services transactions, called Business Transaction Protocol (BTP). BTP supports atomic and cohesive business transactions.

Security is a crucial factor in the reliable utilisation of grid resources which are geographically distributed among autonomous and heterogeneous systems. Current grid security services are based on the combined use of technologies such as PKI, XML and SSH [13, 14]. However, for a grid to be more useful and reliable a much higher level of security service is needed. As different resources in a grid may have different access policies, a computational grid should provide its users with a good security service, including but not limited to: authentication, authorization, credential conversion, identity mapping, confidentiality, and secure computation.

3. The proposed framework

This section presents a new multi-agent framework to ensure effective mediation of grid services. Agents are autonomous entities, which possess a high potential for practical applications in areas such as engineering design, e-commerce and grid computing. The proposed framework incorporates the most common architecture of agents, called BDI (Beliefs, Desires and Intentions). BDI is a procedural reasoning model, which is driven by denoted goals. BDI is an effective reasoning mechanism for applications that need to contend with uncertain and dynamic environments such as grid computing. In the BDI model, Beliefs represent the external and internal informational state of an agent. That is, what it knows about itself and the outside world. Desires (or goals) are an agent's motivational state, that is, what the agent is trying to achieve. A typical BDI agent has a procedural knowledge constituted by a set of plans, which defines sequences of actions to be performed to achieve a certain goal or to react to a specific situation. The Intentions represent the deliberative state of the agent, that is, which plans the agent has chosen for eventual execution.

The framework comprises the following phases:

3.1 Service discovery

This phase dynamically discovers grid services using fuzzy logic and ontological techniques. As described above, the current mechanism for the discovery of grid services is mainly through service directories. Our framework considers such directories as well as other sources to be within the search space of grid services. One of the major issues is that grid services are generally published with little or no description. For example, the Grid Market Directory (GMD) [6] publishes grid services using name, type, provider, price, host, and path (http://jarrett.cs.mu.oz.au:8080/gesi/index.htm). GMD publishes an astronomy service as name = Virtural observatory, type = Astronomy, provider = Gridbus Lab, price = 3.0 dollar (for CPU/sec) and 2.0 dollar (for software), host = belle.cs.mu.oz.au, path = virtural observatory service. In the case of UDDI such as XMethods (http://www.xmethods.com), services are published as publisher, style, service name, description, and implementation tools. For example, XMethods publishes a "Medi Care Supplier" web service and describes it as "Provides names, addresses, and contact information for suppliers that provide services or products under the Medicare program". We use the example of UDDI web services, as UDDI can be used for grid services publishing and discovery.

The above examples of services reveal that it is difficult to determine the detailed specification of grid services such as the data types of the service attributes, the input and output of the service and so on. The description of the grid services is always incomplete. This situation is further complicated in the discovery of grid services which may not be registered with centralised directories and are openly distributed across the network.

One of the key tasks in grid service discovery is matchmaking. In order to resolve this issue, we propose a fuzzy matchmaking mechanism [16] to increase search efficiency and to improve effectiveness by locating appropriate services to the request. The objectives of the proposed fuzzy matchmaking mechanism are two-fold: (i) to enable users to employ imprecise terms in queries in order to uncover appropriate services. (ii) to model the content of service in an effective and efficient way along with the utility of grid service and semantic web technologies in order to shorten the search process.

The fuzzy matchmaking mechanism contains a fuzzy classifier which includes essential knowledge for interpreting and classifying the information residing in grid services. It consists of primitive and composite fuzzy

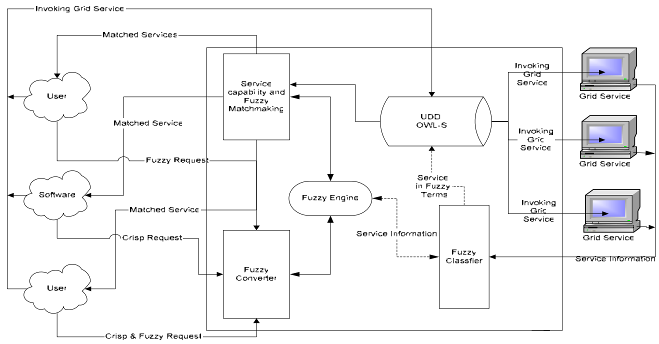

Figure 2. Discovery and Matchmaking of Grid Services

terms, modifier fuzzy terms, and fuzzy rules. Figure 2 shows the proposed mechanism comprising of various components including: fuzzy classifier, fuzzy engine, UDDI, OWL-S, and a fuzzy converter. In the context of matchmaking, two criteria, capability and contents of grid services, are considered. The following briefly describes the different steps involved:

1. The first step is to generalise the contents into fuzzy terms by employing a fuzzy classifier which represents a service or a sub-service as descriptive fuzzy terms based on the information or database residing in the grid service. These terms are loosely structured as a hierarchy via fuzzy rules and the predefined fuzzy sets. OWL-S incorporates the top level for advertisement. However, the rest of the fuzzy terms and rules are represented as an ontology and are stored in OWLJESSKB files. OWLJESSKB is a knowledge based system with the capability of interpreting OWL through its resident inference engine. This is a pre-processing task in order to avoid a slow response time at runtime. The high-level terms are identified and represented in the OWL-S, which is published in the UDDI and available for matchmaking.

2. When a user or software process initiates a query, the fuzzy classifier checks and transforms crisp terms used in the query to fuzzy terms. The fuzzy matchmaking mechanism is triggered by relating objects in the request with other objects represented in the ontology. Capability matchmaking is processed first. If there is a capability match in terms of their parts or types, approximate reasoning is then used to map the fuzzy request to the appropriate contents of services. If the top-level description is not satisfied, the supporting information (fuzzy rules, and other primitive/composite terms stored as OWLJESSKB files) will be imported and investigated. The approximate reasoning is employed to identify the relationship between the fuzzy terms.

3. Once possible matches have been identified, then the software process will be able to invoke the grid service with its original crisp request. If there is any fuzzy term involved in the request, the terms will be translated to crisp terms in order to comply with the format of statements in the pre-condition and operations of OWL-S.

The key task of matchmaking is to identify the possible matched services according to application's requests. The composition of grid services is another important task. Another system we have developed here allows the mismatch services to alleviate their differences if there are no large differences between them [15].

3.2 Service planning and coordination

This phase deals with the planning and coordination of the grid services. Based on multi-agent planning mechanisms, effective plans are devised to select appropriate services from the discovered grid services so that they meet the application's requirements. For instance, there might be different grid services which provide the same service or functionality. For example, an astronomy grid service (http://jarrett.cs.mu.oz.au:8080/gesi/index.htm) may have alternatives which are provided by different service providers which provide similar services but with different prices such as 2.0 or 3.0 dollar (for CPU/sec) and 1.50 or 2.0 dollar (for software).

Agents devise plans [1] to process an application's requests (or fulfil its intentions) by selecting suitable grid services according to the service utility (based on the application's requirements). For example, one possible plan is to obtain the cheapest grid service in terms of CPU cycles or software costs. The criteria for selecting plans are based on their utility and feasibility (e.g., the availability of the cheapest grid service). The selected plans will be ordered according to their utility to reduce the need for regenerating the Applicable Plan List (APL) [1]. APL contains a list of feasible plans. Plans are classified as higher utility plans and lower utility plans

After devising the plans, agents coordinate them based on their utility. Coordination is complicated as grid resources have an unpredictable availability and lifespan. It is difficult to maximise the utility of isolated resources if they cannot be integrated and coordinated properly. For this reason, mechanisms for automating the coordination of services have been developed. The OGSI specification (http://www.gridforum.org/) provides an environment wherein grid services can become more manageable in large and complex distributed applications. The current specification of OGSI does not provide a universal co-ordination mechanism for orchestrating grid services. Further, ontological tools are used to provide grid services with clear meaning and descriptions. For instance, OWL-S [3] is the current standard for defining an ontology for grid (or web) services to provide a richer service description.

We propose to employ OWL-S in order to effectively coordinate the execution of the plans devised for grid services. OWL-S ontology comprises three components including ServiceProfile, ServiceModel, and ServiceGrounding. OWL-S and multi-agents have a symbiotic relationship [2]. Agents can be generated and instantiated from an OWL-S description by the following mapping:

- The ServiceProfile in OWL-S maps to an agent's beliefs (B).
- The ServiceModel is mapped to a set of intentions associated with plans (I). Each activity in the process is associated with a sub-plan. Preconditions and effects from the ServiceProfile will translate into conditions and effects for the BDI plan. The elements in the ServiceGrounding are used to define a set of actions within plans.
- The desire (D) is specified by additional functionality in conjunction with the specification of the ServiceProfile.

The joint use of OWL-S and agent technology has the potential to ensure the appropriate coordination of grid services. Such coordination of dynamic grid services may not be easily accomplished through the existing higher-level coordination protocols such as auction, contract net protocol and negotiation. The auction and contract net protocols are used to select the most suitable grid service provider. This process involves matchmaking activities to ensure that the appropriate grid service is found, before negotiations between agents over detailed plans takes place. The match making activities are fulfilled by a matchmaking model [15], which assumes that grid services are annotated with OWL-S. This model is a self-contained knowledge-based system which includes rules, facts and a reasoning mechanism. Rules identify the relationships between concepts. The derivation of rules is built upon basic definitions of the problems and related concepts.

3.3 Service reliability and security

This phase concerns the reliability and security of the grid services. We first illustrate the techniques for service reliability. This is followed by the description of security aspects.

Service reliability: We define reliability as a system's ability to ensure the correct execution of grid services, to avoid undesirable outcomes of grid services, and to maintain the consistency of data associated with grid services. This definition is based on the concept of reliability of the distributed database transactions [17].

We believe that transaction management (TM) technology can affectively be employed in order to ensure reliability of grid services. As described above, various transactions models are applicable to grid services depending on the nature of the grid application. These include classical ACID (atomic, consistent, isolated, durable) transactions, and the extended transaction models. The latter are extended in the sense that they relax the atomicity and isolation rules of ACID transaction models by allowing transactions to expose their intermediate results to other transactions. Current web services transaction technology such as the OASIS Business Transaction Protocol (BTP) and the WS-Transaction take into account ACID as well as extended transaction models. BTP and WS-Transactions can potentially be used to ensure the reliability of the grid services.

In order to fully exploit the potential of TM technology in grid services, current transaction models should be enhanced with semantic knowledge and multi-agent technology. Agents can employ transaction models in order to reliably execute different plans of grid services. For instance, different actions of an agent's plan can be executed as a transaction thereby maintaining the correctness of the plan and the consistency of the respective data. Consider the execution of an *astronomy grid service* which requires that a user has to pay money in order to consume this service. This may involve actions such as transferring money from the user's account to the service provider's account, and the execution of a service. These actions can be executed as part of a grid service transaction which ensures the reliable transfer of money and the execution of astronomy service even if there are failures.

***Service security*:** As mentioned earlier, security is a crucial factor in the utilisation of grid services which are geographically distributed among autonomous and heterogeneous systems. Since different services in a grid may have different access policies, a grid should provide its users with a good security service, including but not limited to: authentication, authorization, credential conversion, identity mapping, confidentiality, integrity, non-repudiation, availability checking, private information retrieval, secure computation, and virus detection. Current grid security services are mainly based on the combined use of various security technologies such as PKI, XML and SSH [13, 14], which is in turn based one way or another on modern cryptography. Despite of these, it is still not sufficient to meet the security requirement of a grid system. For a grid to be more useful, secure, and reliable, we argue that a much higher level of security service is needed.

Cryptography, particularly public-key cryptography (PKC) is an essential operation in almost all security solutions. A serious problem with the current PKC is that almost all the PKC systems in use base their security on one of the following three computationally infeasible problems: (i) The integer factorization problem (IFP) (ii) The finite field discrete logarithm problem (DLP) (iii) The elliptic curve discrete logarithm problem (ECDLP).

The fastest algorithm for IFP and DLP is the Number Field Sieve (NFS), a variant of the Index calculus, and runs in sub-exponential time. For ECDLP (also applicable for IFP/DLP), the Xedni calculus can be used, but it cannot be run in sub-exponential time. So PKC based on IFP/DLP/ECDLP is secure at present, but of course, it may not be secure in the future. For grid computing, the biggest security threat would be someone who uses cryptography against someone else's cryptography. For example, a user may use a public-key to write a virus program to produce/spread virus over the grid. No-one will be able to detect the virus apart from the virus writer, who has the private key. In this case, the grid will be totally insecure, and the new technology of kleptography will be needed to ensure grid security.

4. Conclusion

In this paper a new multi-agent framework for grid services mediation was presented and a number of research issues associated with current techniques and technologies of grid services were highlighted. These refer more specifically to the dynamic discovery of grid services, the determination of effective planning and coordination for the discovered services, and the secure and reliable utilisation of those services.

The work presented in this paper is part of an ongoing research programme on grid services mediation. Future work on the proposed framework will involve implementation and evaluation through various case studies of grid services.

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