Uniform Information Service Interoperation Framework among Heterogeneous Grids

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Abstract—Currently there is no practical standard for grid middleware, most of the grid platforms are built by their own, and it’s not easy to interoperate these grid platforms. Information service is one of the key components of the service oriented grid system, and information service interoperation among heterogeneous grids is the first step towards grid interoperation. Existing grid interoperability projects mainly focus on immediate bridge mechanisms, which is intricate and of poor scalability. To address the issues, a uniform information service interoperation framework (UISIF) is proposed in the paper, which is based on the idea of mediated bridge mechanisms, and adopts virtual layer and plug-in technology. There are two well-established grid systems in China, ChinaGrid and China National Grid, and they are built with two different grid middleware, CGSP and VEGA. With UISIF, these two grid systems make information service interoperation a reality without changing the codes of current grid systems. The experiments also show that the information service interoperation has low information querying latency and high accuracy; Moreover, UISIF has good scalability based on hierarchical architecture, virtual layer and plug-in technology.

Index Terms—Grid, Interoperation, Information Service, plug-in, CGSP, VEGA

I. INTRODUCTION

As a novel and promising technology, grid technology has gained unprecedented rapid development [1]. A wide variety of grid middlewares and grid systems have been developed in numerous research projects all over the world, such as Globus toolkits, CGSP, UNICORE, VEGA, etc [2, 3, 4, 5]. Existing grid systems are mostly for particular application and there is no practical standard to follow, so many grid systems are developed according to their own specification, which makes interoperation among these grids very complex. Most grid platforms have their own applications, so it’s a nightmare to transfer these applications to a new platform, and re-programming the grid middlewares also take much time. Hence, the interoperability of different grids is essential to the success of grid technology. In order to achieve interoperability between heterogeneous grids, some issues must be addressed such as security, information service, job scheduling and data management [6]. Information service is one of the key components of the whole grid system, which connects all system modules and is responsible for providing a global view of all resources in grid [7, 8]. So, implementation of information service interoperation among heterogeneous grids is the first step towards grids interoperation.

Though grid resources are usually defined according to the XML-based schema or information model, information service of different grids are not easily interoperable for the lack of consistency, which mainly results from two aspects. In one hand, different grid systems adopt specific XML-based schema or information model to describe the resources. In the other hand, different grid systems exploit different mechanisms to discover, organize and store resources information.

Existing grid interoperation projects mainly focus on immediate bridge mechanism, which modifies the original grid systems. This approach would become complicated if we want to interoperate a number of heterogeneous grids. Moreover, the interoperation is not bidirectional [9, 10, 11]. To address the issues, a uniform information service interoperation framework (UISIF) is proposed in the paper, which, based on the concept of mediated bridge mechanisms, adopts virtual layer and plug-in technology. There are two well-established grid systems in China, ChinaGrid and China National Grid, and they are built with two different grid middleware, CGSP and VEGA [3, 5]. With UISIF, these two grid systems make information service interoperation a reality without changing the codes of current grid systems. The main contributions of UISIF lie in the following respects: Firstly, UISIF implements the information service interoperation among heterogeneous grid systems without any change to them, keeping the independence of original grid systems; Secondly, UISIF translates and caches the information retrieved from grid platforms periodically,
which guarantees low information querying latency and high accuracy; Most importantly, UISIF has good scalability based on hierarchical architecture, virtual layer and plug-in technology.

The rest of the paper is as follows: Section II reviews some related work. In section III the interoperability concerns for heterogeneous grid information services are discussed. Section IV introduces the design and architecture of UISIF. The implementation of key components of UISIF is proposed in section V. A prototype is presented in section VI and experiments and evaluation are conducted in section VII. Finally, conclusion and future work are described in section VIII.

II. RELATED WORKS

Interoperation has been an active research area for many years. Traditional distributed computing platforms mainly try to resolve interoperability problems by the means of bridge mechanisms, standard protocol, etc. For instance, Interoperability between DCE and CORBA is achieved by immediate bridge mechanisms [12, 13]. Web Services rely on some simple, yet extensible standards and protocols: WSDL, SOAP, UDDI, and so on. [14].

Recently, a number of efforts have been put to grid interoperability. GRIP (Grid Resource Interoperability Project) implements resources interoperation between UNICORE and Globus by adopting resource broker to some extent [9, 10]. But the interoperation is not bidirectional, that is to say, only through UNICORE client, can users access resources information of Globus system. GPE (Grid Programming Environment) exploits GridBean technology to integrate heterogeneous grid systems [11]. Users can access resources information of multiple grid systems via GPE portal or client access interface which have integrated UNICORE and Globus. It has good scalability but breaks the independence of underlying grid systems. The OMII-Europe project aims to harvest open-source, Web-Services-based, grid software components from across Europe and to supply these grid services in a form that will enable them to interoperate across the platforms: gLite, UNICORE and Globus [15]. It focuses on the re-engineering of software components rather than on the development of new technology.

Aforementioned interoperability mechanisms belong to immediate bridge mechanisms which is direct, simple and effective when the number of platforms remains very small, but when the number of grid platforms becomes large, this approach would become inflexible and intricate since the number of bridges increase exponentially in O(n2), where n is the number of different platforms to be interoperaed.

Based on the idea of the mediated bridge mechanisms, we realize grid information service interoperation by utilizing virtual layer and plug-in technology, which has high flexibility and scalability. In addition, in order to address the problems of low efficiency of the mediated bridge mechanisms, caching technology is adopted in virtual layer.

III. INTEROPERABILITY CONCERNS FOR HETEROGENEOUS INFORMATION SERVICES

In order to efficiently integrate a variety of resources, current grid systems adopt diverse information description and management mechanisms [16]. For instance, different grid systems define different tags for specific information; each grid system has its own uniqueness in organizing, storing and querying service information.

To achieve information service interoperation between heterogeneous grids, some key issues must be considered and addressed. In this section, we identify information service interoperation concerns which will be took into account in the design of UISIF. And they are as follows:

A. Accuracy

To shield the differences of the information descriptions and management mechanisms exploited by various grid services, semantic mapping and translating are effective approaches. During the process of information mapping and translating, accuracy must be ensured so that user can obtain accurate information while querying resources and services across heterogeneous grid systems.

B. Latency

In order to interoperate the heterogeneous grid information services, information description translation is performed between heterogeneous grid platforms, which would bring extra latency and have great effect on the QoS of interoperability. Latency is one of important metrics of QoS and users usually give more attention to it, so when multiple heterogeneous grid platforms work together, some measures, such as caching and prefetching, should be exploited to guarantee high information query response for users.

C. Scalability

Finally, with the join of more heterogeneous grid platforms, UISIF should be easily scalable and extensible as well as guarantee the system performances such as information query response and accuracy.

In addition, as grid is a novel and immature technology and standards are largely under development, heterogeneous grids would coexist for long time. So interoperability must keep the independence of grid systems during scaling.

IV. UISIF

A. Architecture

In order to implement the information service interoperation among various heterogeneous grids and keep their independence, based on the idea of mediated bridge mechanisms, UISIF designs a virtual information service layer by adopting plug-in technology. As shown in Figure 1, UISIF consists of three layers: underlying grid information service layer, plug-in service layer and virtual information service layer.
Underlying grid information service layer is referred to the various information service centers belonging to different heterogeneous grid systems such as CGSP, VEGA, UNICORE, etc, which usually have their own uniqueness. Plug-in module periodically translates the information data retrieved from underlying grid information center to a uniform information format. In virtual information service layer, consistent information repository (CIR) and service agent modules are responsible for caching and managing service information data. Service agent modules provide common information services such as service register and service query.

The remarkable characteristics of UISIF is that firstly system scales easily for the number of plug-ins only grows linearly in $O(n)$, where $n$ is the number of grid platforms to be interoperated. That is to say, adding a new platform only requires adding one plug-in module. Secondly, the CIR in virtual layer can cache the information of each heterogeneous grid platforms which address the problems of low efficiency of the mediated bridge mechanisms. Finally, UISIF keep the independence of original grid platforms without any change to them. Any user, accessing common UISIF interface, or accessing any underlying grid platform, could directly and transparently access service information provided by all underlying heterogeneous grid platforms.

B. Scalability Consideration

To address the challenge of scalability and extensibility resulted from the join of more heterogeneous grid platforms, UISIF adopts hybrid topology as shown in Figure 2, which integrates the advantage of tree mode and flat mode. Intuitively, tree mode is easy to scale but has poor query response. Whereas flat mode has good query response but not easily scales.

In Figure 2, an autonomous UISIF system is called a domain which integrates some heterogeneous grid information services and can work independently. Domains can be interconnected in tree mode, namely, a domain can join another domain as its child. In addition, each domain at the same hierarchy keeps a same copy of the information of its sibling domains. Here, node represents underlying heterogeneous grid information centers, which are integrated in domain through corresponding plug-in.

In UISIF, information service maintains two kinds of information: One is domain information, which mainly includes the topology information of domains, indicating how the domains are connected, and the configuration information of each domain. The other is node information, which provides a global view of all resources in nodes. In our design, UISIF exploits GLUE schema as the consistent data representation, which was proposed as standard in GGF [17] and widely accepted internationally.

V. COMPONENTS

In this section, the key components of UISIF will be introduced and implemented. The specific design of UISIF is shown in Figure 3.

A. Plug-in

Plug-in is one of the key components of UISIF, which serves as a bridge between CIR and underlying grid information service center. The main function of plug-in is to retrieve the information data from underlying grid information centers and translate the data to consistent data representation such as GLUE. In addition, plug-in is responsible for converting the service access command between different information service management mechanisms.
The introduction of plug-in to UISIF improves the scalability and extensibility of system. When underlying grid information centers register with UISIF, corresponding plug-in will be deployed and invoked. In order to provide real time information of various grid resources for end users and other grid systems, plug-in module periodically probes underlying grid information centers and updates the information stored in CIR.

B. Consistent Information Repository

CIR is the core of UISIF, which hides the heterogeneity of underlying grid resource information and provides consistent information description. CIR acts as a cache to address the long latency problems resulted from that almost every message is translated twice by plug-in modules. Currently the resource descriptions used by grid middlewares are different from each other and there is no mature standard available that all systems would adopt. In order to unify various types of resource description mechanisms and be compatible with other description models, GLUE, widely accepted as resource description model internationally, is adopted in CIR. GLUE can describe information about site, service, cluster and storage resources, etc.

In order to support the scalability of UISIF, CIR keeps two types of information: domain information service (DIS) and node register service (NRS). DIS is used to record the whole domain topology information including the access point of information center of each domain, the father-son relation of domains, the number of nodes in each domain, etc. NRS is to maintain the service information of inter-domain and sibling domains including nodes hardware information, deployed services information, relative information of sibling domain, etc.

C. Service Agent

Service agent mainly takes charge of encapsulating the consistent information data and providing a uniform access point for various grid systems and end-users. Service agent is implemented using WSRF technology and collaborates with plug-ins to realize the translation of access commands of various grid information services.

VI. PROTOTYPE

Our prototype is based on Globus toolkit [2] and implemented towards CSGrid environment [18]. CSGrid is launched by Chinese Ministry of Education and aims to promote the interoperability among heterogeneous grid systems. CGSP and VEGA are two representatives of heterogeneous grid systems [19, 20]. They vary greatly in architecture and management mechanism, especially in information service management. In this section, we will first introduce CGSP and VEGA, and then detail how to realize the information service interoperation between them.

A. CGSP

CGSP, the supporting grid computing platform for ChinaGrid project, integrates all kinds of resources in education and research environments, makes the heterogeneous and dynamic nature of resource transparent to the users, and provides high performance, high reliable, secure, convenient and transparent grid service for the scientific computing and engineering research [18]. The current version, CGSP 2.0, is based on the core of Globus Toolkit 4.0, and is WSRF and OGSA compatible [19].

CGSP exploits hierarchical architecture to manage resource information as shown in Figure 4. In CGSP, domain represents an autonomous grid system which can run independently and node provides resources. There is just one information center in each domain, and information centers of different domains can be integrated to provide a global view of a collection of domains, each of which is a collection of nodes. And each node is a collection of resources. In addition, CGSP utilizes XML-based document and XPath language to keep and query the resources and services information.

Figure 4. Architecture of CGSP

B. VEGA

VEGA is developed by Chinese Institute of Computing Technology and is mainly based on standard Web Service technology, which views a grid as a distributed computer system. VEGA adopts three-layer architecture to manage grid resources as shown in Figure 5. Based on the routing concept of router on Internet, VEGA adopts grid router and agora to manage resources which can be categorized.
into physical resource, virtual resource and efficient resource. User can access them through physical address, virtual address and effective address [20]. In addition, VEGA adopts Mysql database and SQL to store and query the information.

C. Implementation

The information interoperation between CGSP and VEGA comprises of two phases: information integrating and information mapping. Figure 6 shows the process of information integrating, the query module retrieves the information from CGSP and VEGA periodically; then the translator module translates the information to a uniform format described by GLUE schema; finally through subscription and publish mechanism, the resource information of CGSP and VEGA are stored in CIR. Figure 7 shows the process of information mapping, through the plug-in and virtual information service layer, resources are mapped between CGSP and VEGA. Figure 8 shows the services information integrated in UISIF of CSGrid which integrates VEGA and CGSP grid systems.

<table>
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<td>1GB</td>
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<td>Sub Domain 2</td>
<td>Opteron 1.6G×2</td>
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VII. EXPERIMENTS AND EVALUATION

UISIF provides a desirable and efficient way to interoperate heterogeneous grid information services. In this section, we evaluate it from accuracy, latency and scalability. The experimental environment comprises eight grid sites which are deployed VEGA or CGSP grid systems, and five UISIF domain sites which are based on clusters. Three kinds of interoperability scalability architectures are shown as Figures 9, 10 and 11. The configurations are shown in Table I.

A. Accuracy

In order to evaluate the information querying accuracy of UISIF, we conduct experiment using flat architecture in Figure 9. As shown in Table II, we deploy 10 GRS applications (Laplace and Image services) in each CGSP platform. Because VEGA system doesn’t support GRS, there are 0 values in Table II. In addition, 10 types of Web Service applications are deployed in CGSP and VEGA platforms respectively. Physical resources in
Table II denote the hardware resources which the grid platforms provide such as CPU frequency, memory capacity, storage, etc. Then we query service information in terms of some key words (e.g. laplace, iterative, image, CPU Frequency, Memory Capacity) in three ways: through UISIF, through CGSP and VEGA. The experimental result is shown in Table II, from which we can conclude that UISIF can achieve desirable information query accuracy, sometime even higher than CGSP and VEGA.

![Image](image1.png)

**Figure 10. Tree architecture**

![Image](image2.png)

**Figure 11. UISIF architecture**

### B. Latency

We evaluate the information querying latency of UISIF in terms of the metric of information query response time (QRT). QRT refers to the average amount of time that elapsed from when a client sends a request for query until it receives the query results. We adopt the same experimental setting as used in above section. Similarly, we query service information using some key words through UISIF, CGSP and VEGA respectively for 30 times with a waiting period of one minute between receiving a request response and issuing the next query.

The results are shown in Table III. Note that there is not big difference in information query response among CGSP, VEGA and UISIF. This is because that by adopting caching technology, UISIF can eliminate the latency incurred by translating the information description between heterogeneous grids and UISIF. UISIF translates and caches the service information of various grid platforms and periodically updates them, which make user finish the query in UISIF instead of in underlying grid platforms.

### C. Scalability

In order to evaluate the scalability of UISIF, we compare UISIF with flat mode and tree mode in terms of two metrics: system throughput and QRT. In our experiment, we simulate up to 500 users sending query to the UISIF systems simultaneously for 10 minutes with a waiting period of one second between receiving a request response and issuing the next request. We evenly distribute the simulated users to two clients who query the service information through sub domain 1 or 2, in addition, 50% of query need be delivered to the root domain server to finish query and the other only be delivered to the domain server.

![Image](image3.png)

**Figure 12. Throughput vs. No. of concurrent users**

Figures 12 and 13 compare the performance metrics of the three models. Figure 12 shows that the throughput of three models increases when the number of users’ query rises from 1 to 500. The throughput of flat mode is higher than that of tree mode and UISIF mode when the number of query doesn’t exceed 200. But when the number of...
query exceeds 200, the throughput of flat mode becomes the lowest and the throughput of UISIF is the highest. Figure 13 illustrates that when the number of query is less than 300, the QRT of flat mode is lowest. But when the number of query is more than 300, the QRT of flat mode is highest and that of UISIF is lowest.

![Figure 13. QRT vs. No. of concurrent users](image)

There are two major reasons to explain what Figures 12 and 13 present. First, as shown in Figure 9, in flat mode, information data aggregation is direct and the query time is short. However, when system scales, the intrusive overhead will increase proportionally, accordingly, the query latency become large and the throughput decreases. System in tree mode is easy to scale but has poor query response. UISIF integrates the advantages of tree mode and flat mode and can adapt to scale while guaranteeing good system performances.

From above experimental results, we can conclude that due to adopting virtual layer, plug-in technology and hybrid architecture, UISIF has better performances in the interoperability among heterogeneous grid platforms.

**VIII. CONCLUSION AND FUTURE WORK**

In this paper, the challenges confronted with the interoperability of heterogeneous grid information services are discussed. To address the issues, UISIF is proposed and analyzed in detail. Based on the concept of mediated bridge mechanism, UISIF adopts virtual layer and plug-in technology to realize the information service interoperation among heterogeneous grids. By adopting hybrid topology, UISIF is easy to scale while guaranteeing the system performances. Finally, with UISIF, two well-established grid systems (CGSP and VEGA) make information service interoperation a reality without changing the codes of current grid systems. The experiment also shows that the information service interoperation has low information querying latency and high accuracy; moreover, UISIF has good scalability based on hierarchical architecture, virtual layer and plug-in technology. In future work, ontology based representation will be considered and applied into UISIF to improve the interoperability.

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