Semantic Resource Discovery with Resource Usage Policies in Grid Environment

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Abstract
Grid Schedulers aggregate the Grid resource that belongs to multiple administrative domains in a transparent manner. The Grid resource providers have their own local resources policies for the resources that reflects the restrictions on the resource what they are providing to the users. However, the Grid users are submitting the user application along with their desired requirements for the job execution. Currently, most of the existing Grid Schedulers discover the suitable Grid resources to execute the application based on the capability of the Grid resources using the keyword based matchmaking that leads to failure of finding out the potential resources. In this paper,I have proposed the semantic based resource discovery mechanism that considers both the resource information and local resource policy information. The proposed work is integrated with the existing scheduler of Community Scheduling Framework (CSF) and tested for the various test cases in the real-time experimental setup. The various performance metrics such as hit/miss ratio, matchmaking time has been measured and analyzed. The results infer that the proposed work enhances the various performance measures compared to the conventional scheduler.
Keywords: *Grid, Semantic, Resource Information, Resource Policy, Scheduling, Ontology.*

1. Introduction

Grid is large scale, distributed and loosely-coupled heterogeneous resources over geographically distributed locations that harnessed together to satisfy the user job/application requirements. The distributed resources form the Virtual Organization (VO) [1] that represents the common rules to enable sharing and selection across the VOs. Grid middleware is responsible to handle the resources available in the Grid resources. The most popular Grid middleware's such as Globus [2], gLite [3] and Unicore [4] deployed in the Grid resource manage the Grid resources belongs to single administrative domain. The Grid middleware has Information Management that gathers the information about the Grid resources, Execution Management that handles the execution of the

job in the Grid resources, Security Management manages the security related issues in the Grid environment, Data Management handles the data management issues such as data storage, data replication and Runtime environment provides the runtime environment for the jobs. However, the main drawback of the Grid middleware is it is possible to manage the resources that belong to single administrative domain only.

To handle the Grid resources that belong to multiple-administrative domains, Grid Schedulers or Grid Metaschedulers have been evolved. It gathers the Grid resources available in multiple administrative domains. The Grid Scheduler retrieves the Grid resource information that includes the hardware details such as operating system, hard disk space, ram memory, number of nodes, kernel version and the software details required to execute the application such as Message Passing Interface (MPI) and etc. The information retrieved from the Grid middleware is an XML format. It is machine understandable, but it is not machine processable that provides only keyword based access to the XML information. To handle these scenarios, the XML information should be represented in a meaningful manner. Grid Scheduling is the process in the Grid Scheduler or Grid Metaschedulers that consists of three main phases [5] such as resource discovery, system selection and job execution. The resource discovery is the process of matching the user application/job requirements with available Grid resources. The matchmaking process can be classified into two types such as syntactic matchmaking and semantic based matchmaking. The syntactic matchmaking is done by the conventional Grid metascheduler that is purely based on keyword matching and discovers suitable resources that exactly matches with the user's requirements. The semantic based matchmaking is carried out on the basis of representation of Grid resources and ontology based description. The semantic matchmaking discovers the suitable resources that may fall into the three categories [6] such as exact, plugin and subsume.

In addition to that, the large scale Grid environments are generally complex that involves multi-institutions and the resources in the Grid are autonomous in nature.

However, the resources belong to different organizations and have their own policies. They have their own restrictions, for example, number of hours the organizations can contribute their resources to the Grid. Managing these resources and coordinating them in solving a typical Grid application is a challenging task. In such an environment, we need a mechanism that allows the resource provider to express and enforce such usage policies. The Grid Scheduler should verify these resource usage policies against the user's job requests in addition to capability matching with available resource information. Furthermore, the Grid scheduling mechanism should consider the resource usage policies before scheduling the user application to the resources to ensure and delivery of requested user requirements. To handle all the above said issues, there is a need for the mechanism in the Grid metascheduler that should be semantically presented in the ontology knowledge base and retrieved from the ontology knowledge base. The resource discovery process in the Grid Scheduling discovers the potential resources from the knowledge base in a semantic manner that is capable of satisfying the user job requirements. To improve the Grid resource management process by incorporating efficient description and discovery, the resource information obtained from middleware and the policy information is converted and represented in the ontology representation that constructs the knowledge base. In brief, the contributions of the work summarized as follows:

- Design of Semantic description module that semantically expresses both the resource information and local resource policy information.
- Design of Semantic based matchmaking module that filters the Grid resources that are capable of matching the user job requirements and resource usage policies.
- Design and Implementation of Policy Management Service in Middleware level.
- Integration of the Ontology based semantic description and semantic discovery with conventional metascheduling mechanism
- Comparison of conventional metascheduling approach with proposed approach.

The rest of the paper is organized as follows. Section II provides the works that are related to Grid Scheduler, semantic matchmaking, policy based matchmaking in the Grid environment. Section III describes the proposed architecture that includes semantic resource discovery, policy matchmaking system and policy aggregator. Section IV describes the implementation details of the proposed architecture. Section V discusses the details about experimental setup and the test results. The final section concludes this proposed research work and explores the possibility of future works.

2. Related Works

Huedo et al. [7] proposed the Gridway metascheduler that is compatible with Globus Grid middleware. It has the support for the aggregation of Grid resource information, perform the keyword based matchmaking to discover the potential resources that matches the application requirements and finally scheduling the jobs across the grid resources. Emir Imamagic et al. [8] proposed condor a cluster manager tool that has the support for the submission of jobs across clusters. The Workload Management System (WMS) implemented in gLite middleware uses the condor for matchmaking the user's application requirements with the available resources in the Grid. Condor mainly uses the ClassAds as the language for job description However, with this representation, it is not possible to understand the semantic relationship between the available resource information and the requested ones.

Rinaldi. M [9] has proposed a novel metric to measure the semantic relatedness between words. Their approach is based on the ontology represented using a general knowledge base for dynamically building a semantic network. Using their proposed approach it is possible to obtain an efficient strategy to rank the digital documents from the Internet according to the user's interest domain. Ming et al. [10] proposed a generic and scalable ontology mapping approach based on propagation theory. The proposed approach is mainly utilizes the linguistic and structural information that measures the similarity of different elements of ontologies in a vector space model. The above two works mainly depends on similar information retrieval in cluster of documents present across the Internet. Corcho et al. [11] proposed a reference architecture that extends OGSA to support the explicit handling of semantics, and defines the associated knowledge services to support a spectrum of service capabilities. The Semantic OGSA defines a model, the capabilities and the mechanisms for the semantic grid. It proposes to extend the capabilities of grid middleware to include semantic provisioning services. Harth et al. [12] provided an ontology based Matchmaker Service that supports dynamic resource discovery and resource descriptions. However, the request is expressed using request ontology and hence there is a need to compile the user request as ontology descriptions. Zhang and Wang [13] proposed a semantic Grid infrastructure for e-governance applications. They stressed the necessity of such infrastructure for management of e-governance resources in the form of services across virtual government agencies. Hartung et al. [14] provided a platform and a metamodel that allows the user to create and edit Grid related metadata present across the Grid infrastructure. They have implemented their proposed work in German D-

Grid. However, the main aim of the proposed work is to design and develop semantic based description and discovery for Grid resources that should be integrated with Service Oriented Grid Schedulers.

The Grid Interoperability Project (GRIP) [15] mainly aimed to address the problem of resource description in resource broker level context and it is mainly responsible for managing the different versions of Grid Middleware such as GT2, GT3 and Unicore. Thamarai Selvi et al. [16] has proposed the semantic discovery mechanism for managing the virtualized Grid resources. However, all the above mentioned works consider the semantic description and discovery of Grid resources and they have not discussed anything regarding the resource usage policies. Wieder et al. [17] proposed a Grid Scheduling Ontology which semantically describes the scheduling criteria and establishes the relationship between various scheduling attributes. Dumitrescu et al. [18] proposed a model for facilitating resource usage policy based allocation in grids. Their proposed model is integrated with Maui scheduling mechanism. Feng et al. [19] proposed a mechanism to express resource usage policy and its enforcement in grid. It uses request response paradigm based on XACML and introduces relevant attributes to express and enforce grid resource usage policies.

3. Proposed System Architecture

The proposed system architecture is shown in Figure 1.

A. Client Handler Service

The Client Handler Service fetches the client requests from the user. The job parser in the client handler parses the requests and store it in the client request pool. The parsed requests are sent to the semantic discovery manager.

B. Semantic Discovery Manager Service

The semantic discovery manager consists of two main modules namely semantic description and semantic discovery. The primary objective of this component is to describe the resource information and resource usage policy information semantically. For this, it needs two components semantic description and semantic discovery component.

Semantic Description: The core part of the semantic component is the Grid Resource Ontology template. The structure of Grid Resource Ontology template represents any resource that can be modeled as an instance of a specific concept provided that the resource can be described using the properties defined in that concept. It is a domain specific ontology that provides hierarchy of concepts along with properties to define their characteristics. Protégé is an ontology editor used for creating ontology using Web Ontology Language (OWL) [20]. The semantic description module retrieves the two types of information such as Grid resource information and Grid resource usage policy information.

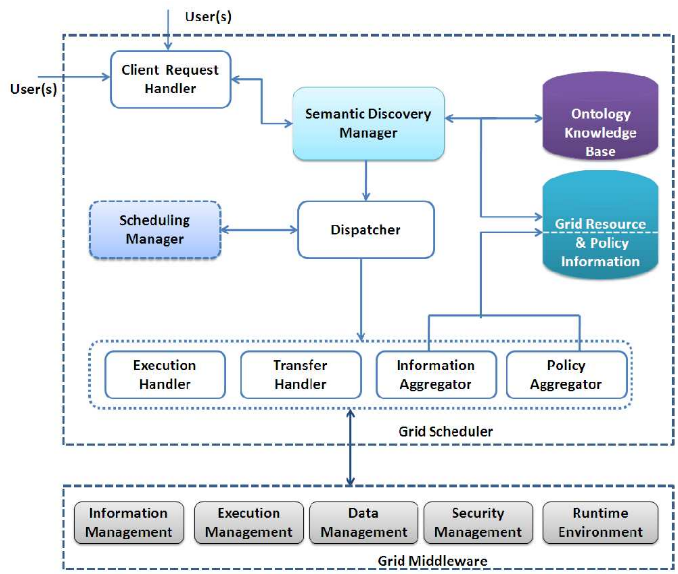

Figure 1: Proposed System Architecture

Grid Resource and Policy Information: The Grid resource information is retrieved using the Monitoring and Discovery Service (MDS) that is available in the Grid middleware in the Grid Scheduler level. This component retrieves the Grid resource information in a hierarchical manner. The retrieved information is updated in the ontology template. The ontology template represents the various Grid resource information properties such as type of operating system, kernel version, processor speed, number of nodes, ram speed, hard disk space, storage space and etc. The Grid resource usage policy is retrieved by the Policy Aggregator which is integrated with Grid Scheduler. The resource usage policy is expressed using the WS-Policy which is an XML based language. The policy information represents the following parameters such as percentage of hard disk space, RAM space contribution to Grid, number of nodes contribution to Grid, period of availability and etc.

The semantic description component is responsible for constructing the knowledge base for the Grid resources. The knowledge base creation and updation by the semantic description component is shown in Figure 2. The Resource

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Information Updater/Parser updates the Grid resource information whenever the resource information is retrieved by the MDS component. It parses the updated information and the same has been updated in the ontology knowledge base. The Policy Information Updater/Parser updates the policy information about the resources whenever the policy information is retrieved by the Policy Aggregator component. It parses the same information and the same has been updated in the knowledge base. After retrieved the Grid resource information Grid resource usage policy information the Protégé-OWL APIs are used to dynamically to create and update the instance of a particular concept by assigning values to appropriate properties in the ontology template.

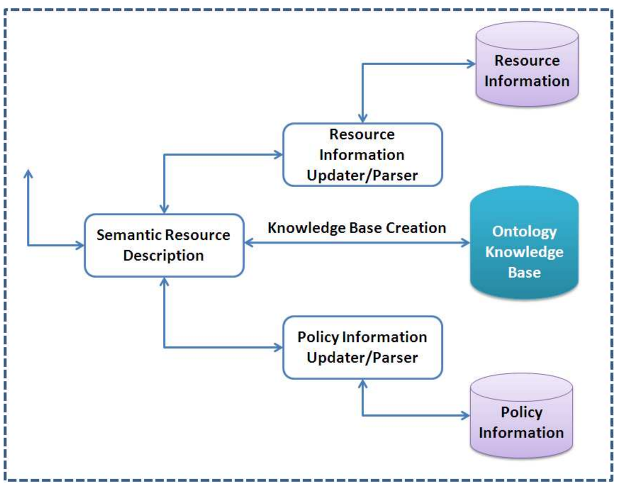

Figure 2: Semantic Description of Resource and policy Information

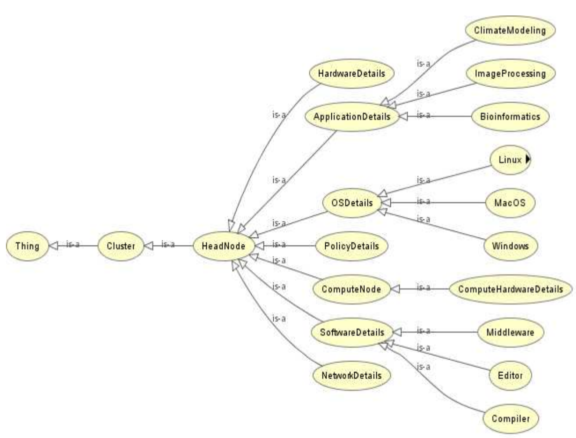

Figure 3: Ontology Description of Grid resources

Semantic Discovery: This component is mainly responsible for discovering the suitable Grid resources that are capable of executing/running the application. This component has incorporated with matchmaking algorithm. The power of the matchmaking mainly relies upon the reasoners; I have made use of the Algernon as an inference engine to retrieve the information from the knowledge base. It retrieves the request from the Client Handler, the requests consists of hardware and software requirements such as operating System, number of nodes required, kernel version, ram space, hard disk space and etc. and software libraries such as Message Passing Interface (MPI), gcc compiler and etc. The semantic discovery component constructs the Algernon query based on the user application requests. The constructed query is executed on the knowledge base. The query considers the user application requirements and the resource usage policy information. Based on the above two types of information, the Algernon query finds out the suitable resources that are capable of executing the application.

The resource discovery module proposed in this work implements an ontology based matchmaking mechanism that determines semantic relationship between the request and the advertised resource information and hence determines closely related Grid resources when exact match fails. The algorithm classifies resources into three broad categories, namely exact, resources that exactly match the requested resource requirements, subsume, if the advertised resources have more capabilities than that of requested, plugin, an exact contrary to the previous case, that is, the application expects more capabilities than the advertised capabilities, and disjoint, which actually is not a match but infers that both the request and the available resources are completely different. The constructed query determines the semantic relationship between the user request and the available resources. The semantic discovery manager invokes the semantic discovery component is shown in Figure 4. The semantic discovery component invokes the Algernon Inference Engine. The Algernon Inference Engine invokes the ontology knowledge base for query execution.

C. Dispatcher: Once the resources are identified by the semantic component, it sends the job requests to the Dispatcher. The dispatcher invokes the scheduling manager to select the resources from the discovered resources and execute the user application.

D. Transfer Manager: The transfer manager is responsible for transferring the required files to the Grid resource. It makes use of the Gridftp and Reliable File Transfer (RFT) protocol to transfer the required files. This service is responsible for two purposes: First it transfer the executable, input files to the scheduled Grid site. Second it transfers the generated output files to the Grid Scheduler and the same has been provided to the user.

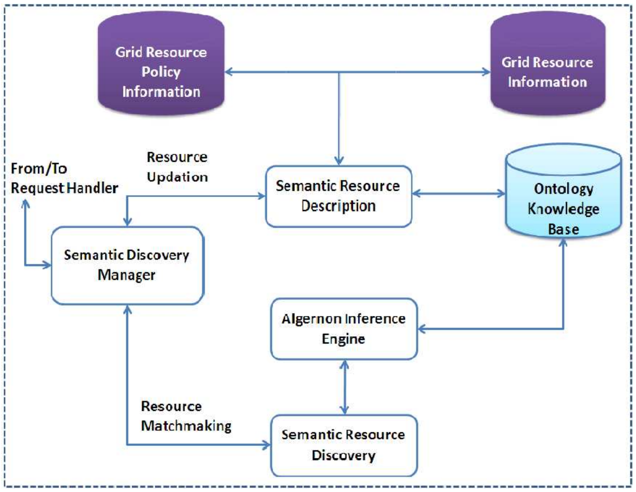

Figure 4: Semantic Resource Discovery

E. Execution Manager: The execution manager is responsible for managing the execution of jobs. It interfaces the Grid Resource Allocation and Management (GRAM) in the Grid site and execute the jobs. The Execution Manager service monitor and update the job status in the Grid scheduler in a periodic manner.

4. Implementation Details

The services have been implemented as Grid services and it follows the Web Service Resource Framework (WSRF) property. The developed services has been deployed in the Grid middleware of Globus Toolkit 4.0.3. The Protégé Editor 3.4.8 is used for creating the ontology knowledge base and the Algernon 5.0.1 is used as an inference engine.

4.1 Semantic Description and Discovery Service

The Semantic Description and Discovery Service retrieve the application requirements from the Client Handler Service and constructs the query based on the application requirements dynamically. It periodically accesses the repositories of resource information and policy information and update resource and policy information about the grid resources in the knowledge base using the ontology template. It does the matchmaking process by matching the user's application requirements with the resource and policy information available in the ontology knowledge base. The constructed query is executed in the ontology knowledge based and the Algernon is used as an inference engine that supports both forward and backward chaining rules. The discovery module returns the matched resource list that satisfies the user requirments and resource policies.

4.2 Resource Information Aggregator

The resource aggregator acta as an interface between the Grid middleware and the Grid Scheduler.It aggregates the resource information retrieved from MDS.

4.2 Policy Aggregator Service

The policy aggregator acts as the interface between the Policy Management Service that is deployed in the Grid middleware and the Grid scheduler. The Policy aggregator retrieves the policy information and the same has been updated in the policy repository. It is an XML based repository that deals with the explicit policy requirements.The policy aggregator aggregates the policy information retrieved from the policy information service.

4.3 Grid Policy Management Service

The Grid Policy Management Service is developed to create the resource usage policies. It is deployed in the Grid middleware level. This service makes use of the policy schema and creates the XML based WS-policy. This service has implemented with policy creation, deletion, updation and display functions. This service creates the resource uasge policies.

5. Experimental Setup and Testing

The following experimental setup as shown in Figure 5 has made in our computer science laboratory for testing the proposed work. The experimental setup consists of three grid resources namely centcluster.pune.uni.in, installed with Cent OS 5.5 as operating system and it has one head node and 10 compute nodes, fedoracluster.pune.uni.in is installed with Fedora Core 12 as operating system and it has one head node and 15 compute nodes and redhatcluster.pune.uni.in is installed with Red Hat Enterprise Linux 5.0 as operating system with one head node and 5 compute nodes. The Grid resources are installed with Globus 4.0.3 as Grid middleware and torque 2.3.x as local resource manager. The Ganglia 3.2.1 is used as the information provider to retrieve the processor related information and Network Weather Service (NWS) tool 2.13 is used as the network monitoring tool to retrieve the network related information. The cluster resources has the capability of 3 GB RAM, 220 GB hard disk, 3300 MHZ as processor speed.

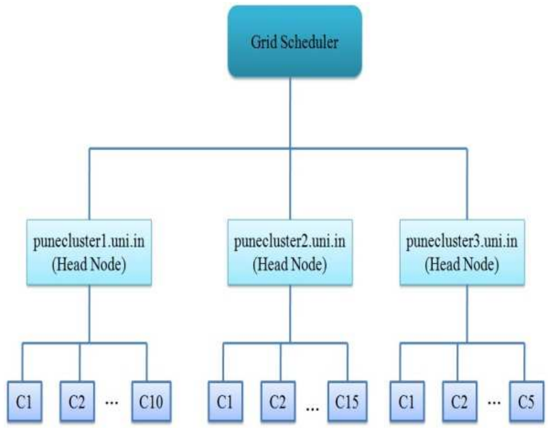

Figure 5: Experimental Setup

To test the proposed work in the real time environment several experiments have been carried out with the semantic component to determine the performance with respect to the following aspects:

5.1 Experiment-I

The performance of the proposed semantic based matchmaking is evaluated by comparing the amount of results obtained from conventional keyword based matchmaking with available Grid resources. Semantic description module is made to run periodically across the Grid resources that contacts the MDS, aggregate resource information, and creates ontology knowledge base. The queries were all converted into Algernon query and executed over knowledge base for resource discovery. Based on the experimental results, it has been concluded that the semantic based matchmaking mechanism retrieved more closely matching resources and thus resulted in greater 'hits' than that of the conventional keyword based matchmaking mechanism. This is because, even though the resource requested by the user is not exactly matching with available resources in the knowledge base, the semantic component retrieved resources in exact, subsume and plugin region. Based on the discovered resources the Grid scheduler selects the resources the resource for execution.

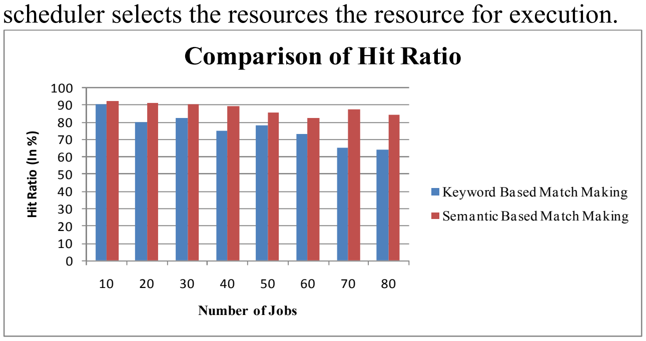

Figure 6: Comparison of Hit Ratio

5.2 Experiment-II

The second experiment was carried out to analyze the matchmaking time in the matchmaking systems. Every Grid scheduler uses its own matchmaking strategy for discovering suitable resources. The conventional CSF Grid scheduler doing the matchmaking process based on the keyword. In semantic based matchmaking the information is retrieved from the ontology knowledge base and matchmaking is carried out. The matchmaking time is more in the semantic based matchmaking time compared to keyword based matchmaking and it is shown in Figure 7.

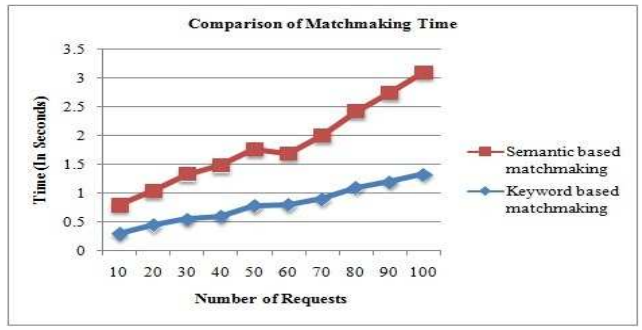

Figure 7: Comparison of Matchmaking Time

5.3 Experiment-III

The third experiment was conducted to analyze the number of resources can be discovered by considering the resource usage policy. I have generated a sample of 10 to 100 job requests and I generated the Grid resources of 100 to 200. First I carried out the matchmaking process only by considering the capability of resources then I have carried out the experiment by considering the resource policy. The matchmaking process considers the resource policy filters the lesser number of resources that are capable of execute the job compared to semantic based matchmaking. The results are shown in Figure 8.

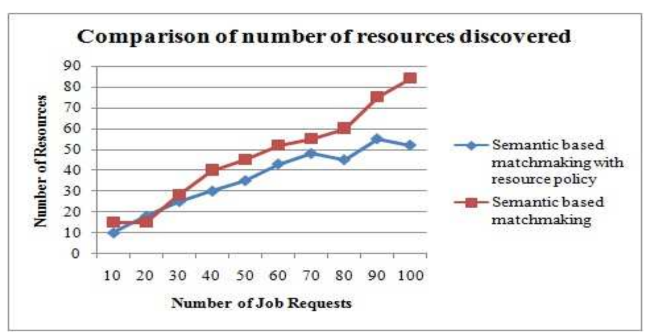

Figure 8: Number of resources discovered

6. Conclusion and Future Work

To manage the Grid resources belongs to multiple administrative domains, there is a need for Semantic based resource discovery with resource usage policies. In this proposed work, I have incorporated the semantic description of resource and policy information in a semantic manner. In addition to that, I have incorporated the semantic based matchmaking based on the resource and policy information available in the knowledge base that is capable of locating the resources not only in exact region but also in plugin and subsume region.The proposed work is integrated with the existing scheduler of Community Scheduling Framework (CSF) and tested for the various test cases in the real-time experimental setup. The various performance metrics such as hit ratio, matchmaking time and number of resources discovered by incorporating the resource policy in the semantic knowledge base has been analyzed. The output of the proposed work is very much helpful for the Grid scheduler to take scheduling decisions for resource selection and job execution.

In future, the Qos parameters can be incorporated for the further filtration of the resources and Semantic similarity among resources can be calculated for selecting more appropriate resources for the execution of the user applications.

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