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A Novel Approach for Grid Resource Management Based on Fuzzy Logic and Semantic Technology

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Abstract— **One of the important challenges in grid is quality of service (QoS) for all the accepted users or applications, while increasing the utilization of resources through resource sharing. An effective resource management approach must guarantee the QoS and balance the load among grid nodes which are frequently highly dynamic and heterogeneous. Grid resources are commonly varied regarding their software and hardware formations. Collecting and supervision of these resources, and discovering appropriate resources is an important topic. So semantic can be very useful for resource discovery and resource selection. Fuzzy theory is another intelligent approach which is applied in our approach to solve uncertainty in resource discovery. In this paper, a novel approach, which is using semantic and fuzzy theory, is proposed to discover grid resource in Grid environment. Search expressiveness, efficiency and scalability, precision and also discover more related resources are the characteristics of the proposed framework.**

Keywords—**Trust, Reputation, Fuzzy theory, Ontology, P2P Grid**

I. Introduction

Because Cloud Computing is an inexact word, there are quite a large number of different definitions for Cloud Computing and there is no general agreement about what a Cloud is. According to Cloud Computing compute won't be done on local computers, and run centralized facilities by third-party compute and storage utilities [1]. Essentially, Grid computing brings resources together in order to achieve something that was not possible before [2]. In the central of 1990s, the name Grid was coined to depict technologies that would allow buyers to earn computing power on requirement [1]. Grid is a distributed system which provides sharing, selecting and aggregating of geographically distributed resources [3, 4]. In grid, resources can be any type of machines such as personal computers, software, etc. The most significant characterize in distributed systems is speedup and also the availability of suitable resources [5, 6]. Cloud Computing extends over with Grid Computing and surely it is developed without Grid Computing and counts on Grid Computing as its foundation support. So for the first glance it seems that "Cloud Computing" is just a new name for Grid because of their similar vision. But in fact they are not the same. They are different in Business Model, Architecture, Resource Management, Programming Model, Application model and Security Model [1].

Semantic grid is an expansion of the common grid in which resources and services are given a well-defined meaning, better enabling computers to work in collaboration [7]. Semantic grid, as semantic web technologies, enables merging resources in definite domains on the grid and makes easier mechanization of middleware tasks, such as selecting grid resources based on their needs [8].

The most important factor for a successful grid resource management is the quality of the available information about software tools and grid resources. Strategies for application scheduling and scheduling algorithms are based on descriptive statements of resource attributes and applications necessities and preferences. So, the way how this knowledge is arranged, and made ready for use performs an adequate role in resource selection. Resource discovery and resource selection are built around the attainable resources and metadata. Grid metadata infiltrates and links them.

Accomplishment of tasks can be influenced by grid metadata design in distinctive and related ways. To address this issue on the grid we can use a semantic approach dependent on ontologies, designed for effective application execution. The quality of information about grid software and resource can be improved by ontologies. By using ontologies, domain knowledge can be reused, common understanding about domain concepts can be shared, definition of domain assumptions can be described in detail and interoperability improvement among other important features, in different grid domains can be achieved. A beneficial grid ontology is comprised a taxonomy of grid concepts, attribute, and axioms which can be reused in different contexts and by other ontologies. Such ontology, connected to inference tools, provides an elastic and forceful way of reasoning about grid components [9].

Resource management system (RMS) is responsible to detect the most adequate nodes that are connecting to RMS. In the grid environment, communication links are responsible to connect resources to each other via communication links. Information exchanging and conversing are be done via these communication links. Several link topology approaches from centralized approaches to fine-grained fully distributed approaches can be used; among them we can point to single node, star, ring, tree, graph, and hybrid approaches [10]. Tree topology and star topology are the most real topology of a grid environment. In the tree topology, the RMS is the root of the tree and other nodes are individuals or arrangements which are members of the grid. In most of the researches star topology is the most popular topology.

Resource management can be performed in three ways: centralized, hierarchical, and decentralized [11]. In centralized approaches, the management strategies are made by a central RMS for all the applications in the network. The RMS preserves all information about the jobs and keeps a record of all available resources in the network. Centralized management organization is good for small grids, but it is not scalable [12]. The grid resource management using centralized RMS gives grid middleware developers a user friendly interface to manage grid resources. They maintain resource information with the aid of centralized databases [13]. This topology gives an abstract model of resources and services and does not have any ordinary mode failure [14, 15]. Figure 1 shows the routine of resource management based on star topology.

In this paper with the aid of fuzzy theory and semantic technology we propose a novel centralized resource management approach for small grids. The focus of our approach is on resource discovery and resource selection. In our scheme, fuzzy theory is used by 3 parameters to detect the most adequate node; Delay, Free space of each node (this parameter is for load balancing) and the semantic similarity between resources and queries.

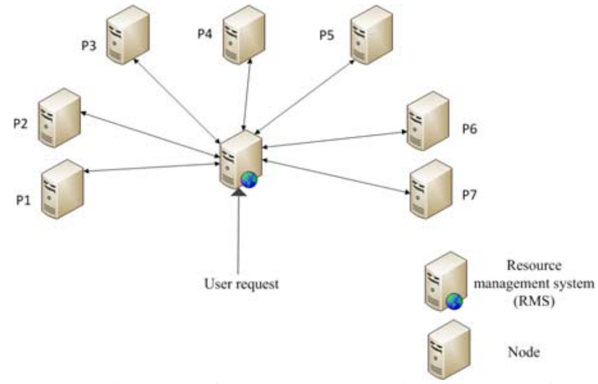

Figure 1- The routine of resource management based on star topology.

The rest of this paper is as follows: in next section we take a brief look at fuzzy theory and semantic web as background; then in section III we provide related works. The proposed approach is presented in section IV. The performance evaluation and experimental results are presented in Section V. Last, in section VI, we conclude our work.

II. PRELIMINARY

This section encloses an introduction fuzzy theory and semantic web as background.

A. Fuzzy theory

Fuzzy Logic [16] proposes some singular characterize that make it an especially pleasant option for many control problems. Fuzzy Logic handles the examination of information by using fuzzy sets, each of which may stands for a linguistic word such as “Cold”, “Low” *etc*. Fuzzy sets are depicted by real values over which the set is mapped, called domain, and the membership function. A membership function appoints a truth value between 0 and 1 to each spot in the fuzzy set’s domain. Based on the shape of the membership function, various types of fuzzy sets can be used. A Fuzzy system essentially comprises of three parts: fuzzifier, inference engine, and defuzzifier. The fuzzifier maps each crisp input value to the corresponding fuzzy sets and appoints it a truth value or rank of membership for each fuzzy set. The fuzzified values are treated by the inference engine, which comprises of several approaches for inferring the rules. The rule foundation is simply a series of IF-THEN rules that narrate the input fuzzy variables with the output fuzzy variables applying linguistic variables, each of which is depicted by a fuzzy set, and fuzzy operators AND, OR *etc*. The integrated verity of the predicate is decided by insinuation rules such as MIN-MAX and delimited arithmetic sums. All the rules in the rule-base are adapted in a parallel manner by the fuzzy inference engine. Any rule which fires donates to the final fuzzy explanation space. The inference rules control the behaviour in which the resulting fuzzy sets are copied to the final fuzzy solution space. The defuzzifier executes defuzzification on the fuzzy solution space. That is, it finds a single crisp output value from the solution fuzzy space.

Common defuzzification techniques are centroid, composite maximum, composite mass, *etc.* Details of the fuzzy logic can be found in [17]. Considering Fuzzy theory, we can have some answers to this question, if the specific node is the adequate node to allocate resource? The answers can be 1 (Yes/True), 0 (No/False), 0.88 (Almost true).

B. Semantic Web

Recently, semantic technology has usage in many domains such as knowledge management, web services, grid resource discovery, cloud service selection etc. Tim Berners lee, has presented the idea of semantic web [18]. In 2001, he paints his outlook to present his innovation as follow: "As semantic web is development the daily typical of our work is will be done by some machine that will talk to each other." Semantic web is comprised of four ingredients [19]: Ontology, metadata, logic and Semantic agents. Ontology is the major part of semantic web and presents well-meaning concepts and relations among objects and puts some restriction on the concepts with the help of some semantic languages such as RDFS and OWL.

III. Related Works

In this part we take a brief looks at some works about semantic grid resource management. Habib Esmaeelzadeh Rostam et al. [5] proposed a resource management scheme which uses node grouping based on (Quality of Service) QOS. Semantic, delay and band width are the criteria that are used for node grouping. Using node grouping will increase the speed and precision in resource management. In this scheme all groups are organized hierarchically and only three groups are placed in the highest level and one of these super nodes and its subgroups will be used for resource management. The requests for resources are assigned to one of groups, and it is directed to the lower subgroups, until it arrives at the desired resource. Each node can be placed in three groups and, thus association and aggregation collection operation will be used. This scheme has a very low load balancing.

Alexandre et al. [9] proposed semantic grid resource management scheme which is based on the association between resources and they are grouped based on semantics. It presents a set of connected grid ontologies and describes how this semantic approach can be used on grid environments and how resource matching requests for scheduling application execution. This scheme proposes a Semantic Grid Integration Architecture to be used for grid knowledge base maintenance and to explore the described scenarios and a prototype is used to integrate grid middleware as its base. The prototype uses the integrated grid middleware.

Balachandar et al. [20] proposed a four-layered conceptual Grid architecture in which OWL is used as a semantic language and Algernon which is the rule-based inference engine is used for information retrieval from the ontology knowledge base. To incorporate semantic component with different Grid middle wares, the implementation of semantic component is not tightly couple with the underlying Grid middleware. It uses the typical way of interacting with the Grid middleware and automatically creates ontology description of Grid resources. In this approach knowledge layer is placed at the top of the Grid scheduler in the high-level Grid middleware layer. The semantic component carried out in the knowledge layer provides for ontological representation of Grid metadata.

Felix Heine et al. [21] proposed a scheme for grid resource discovery which uses ontology based peer to-peer search network for Grid resources. This scheme uses a distributed ontology between nodes instead of using a central ontology. Each node's ontology will be completed by the other node's ontology. In this approach Description Logic (DL) systems and distributed hash table for semantic description are used. DL system is a knowledge representation system. In this kind of system knowledge is divided into two parts: Taxonomical-BOX that stores conceptual knowledge on objects and Assertional-BOX that represents concrete knowledge on individuals. This scheme has a low load balancing.

Somasundaram et al. [22] proposed a scheme for discovering semantic resources in which knowledge layer is uses on grid architecture. This scheme uses a five layered architecture in order to build semantic grid infrastructure and manage information services. Knowledge layer is the top layer that provides services, which can look for patterns in existing data repositories and manage information services. Ontology provides the ability of defining concepts and relations between resources and put some constraint on these concepts with the aid of Web Ontology Language (OWL) which is the most popular semantic language. This scheme has a high load balancing.

FuFang and DeYu [23] proposed fuzzy based algorithm for grid resource management which uses hybrid clustering of grid resources and tasks. Based on this algorithm some parameters such as CPU main frequency (CPU f), CPU free rate (free CPU), total memory size (all MEM), available memory size (avl MEM), available network bandwidth (avl NB), available disk space (avl DISK), etc., to describe the grid resource are used to construct a vector (namely resource vector) to represent given grid resource. In assigning grid resources to grid tasks step resource vectors and task vectors will be put together to compose hybrid vectors of grid resources and tasks. Sequentially, fuzzy clustering on the hybrid vectors will be done, in order to divide the vectors into several groups. Finally the clustering result from the equivalent matrix will be achieved.

Jorge Ejarque et al. [24] proposed a general framework which uses prediction for resource allocation. This framework unites prediction techniques with semantic technologies, which initiates semantic knowledge to the data appraised by predictors, and multi-agent systems. Predictions obtained from the semantic historical data are considered by a group of agents for allocating different jobs in the most adequate resources.

This scheme uses a resource allocator distributed across multiple agents based on the Multi-Agent Resource Allocation (MARA) approach whose decision are based on predictions based on historical data. Job Agents are responsible for managing the jobs and Resource Agents are responsible for managing the resources. The framework that is used in this scheme contains a Semantic Metadata Repository (SMR), which includes the semantic resource statement recorded in the system, and the Historical Data Repository (HDR), which contains semantically annotated logs from system events, that is important to make predictions for current jobs. All the data stored in those semantic storerooms is depicted based on a shared ontology giving a distributed framework for semantic data.

Juan Li and Son Vuong [25] proposed a semantic community-based P2P model approach for providing resource discovery in grids. The system groups nodes into communities based on their semantic characteristics. Due to the similarity between grid networks and social networks this scheme uses this theory to produce communities and also it classifies nodes by the major ontology of their resource property. This scheme uses a SkipNet category overlay, to aid nodes to find other nodes sharing similar interests. SkipNet is a climbable overlay network. Nodes in the SkipNet are arranged into a circular distributed data structure, which contains multiple levels of rings. Each SkipNet node has a numerical ID and a name ID.

Abdul Khalique Shaikh et al. [26] proposed a centralized grid resource discovery approach which uses semantic technology. In this paper a semantic similarity function is used which is defined in [27]. In this scheme annotated resources are registered and indexed in Grid Information Service which is located in RMS. By using semantic technology, this scheme improves job success probability and utilization of resources for grid resource discovery.

Recently, so many attentions have been paid to the usage of semantic grid in Web OS. Web OS is a distributed Operating system which can be implemented by grid [28]. The influence of semantic technology for improving resource management in typical web operating systems has studied in the previous work [29]. This paper illustrates how annotating web OS resources can improve the quality of resource management rank as well as the fault tolerant in front of Web Operating System resources.

IV. THE PROPOSED APPROACH

In our approach, a fuzzy logic model is used for detecting the most adequate node. This approach is based on fuzzy logic that receives some parameters as input. This non fuzzy numbers will send to fuzzy inference system and an adequate rate will be assign to each node to figure out the rank of being adequate for resource allocating; and finally after defuzzification step non fuzzy number output will be achieved. Figure 2 shows the structure of fuzzy logic controller in our scheme.

Fuzzy inference system consists of 5 parts: fuzzifier, implementing fuzzy operators, implementing signification approach, Aggregation of the rule outputs and defuzzifier. Mamdani approach is the most commonly used fuzzy inference technique which we used due to its simplicity [17]. The process is performed as following.

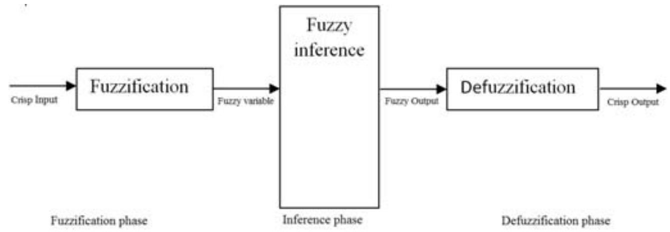

Figure 2- Structure of the fuzzy logic controller in our scheme

Fuzzification of the input the distance of RMS to its connecting nodes, allocated space of each node and the availability of annotated resources - taking the crisp (non-fuzzy) inputs from each of these and finally the degree to which these inputs belong to each of the adequate fuzzy sets will be achieved. Then with the using of fuzzy rules fuzzified inputs will applied to the consequent membership function; after that the process of unification of the outputs of all rules will be done and finally Defuzzification step to achieve crisp (non-fuzzy) number, will be done. The following metrics are the inputs parameters for fuzzy system.

A. Delay

We define Delay, with the fuzzy set definition: {Low (L), Medium (M), and High (H)}.

We assume nodes close to RMS geographically have less delay.

The keynote is, this distance according to fuzzy rules will be placed in multi levels. For example if the distance is 250, it will be placed in low level, medium level and high level with different membership degree. So to determine in which level it will be placed, we use membership function and membership degree. A membership function in fact is a curve that shows how a point in input space will be mapped to membership value in output space. μ shows the membership degree and it is a number between 0 and 1. For example, 250 with the membership degree of 0.2 belongs to medium level, and with the membership degree of 0.8 belongs to low level, and with the membership degree of 0 belongs to high level. Figure 3 shows membership graph for this parameter. It means: $\mu_A High(X) = 0.0, \mu_A Medium(X) = 0.2, \mu_A Low(X) = 0.8$

In general we have equation 1:

$$\mu_A(x) = \text{Degree}(x) \text{ in } A \qquad \forall\, x \in X : \mu_A(x) : X \rightarrow [0,1] \qquad (1)$$

B. Free space of each node

As we mentioned earlier the focus of our work is on resource discovery and resource selection. In order to consider load balancing this parameter is used as one of the fuzzification numeric inputs. In resource management load balancing should always be considered. It means none of the nodes are overwhelmed and the network traffic will be low. A node with the more free space is more adequate for resource management. We define allocated space of each node, denoted as FSN, with the fuzzy set definition: {Low (L), Medium (M), and High (H)}.

Figure 4 shows membership graph for this parameter. For example consider a numeric input: 0.35 is a non-fuzzy number with the membership degree of 0.2 belongs to Low level, and with the membership degree of 0.8 belongs to Medium level, and with the membership degree of 0 belongs to high level.

It means:

$$\mu_A High(X)=0.0, \mu_A Medium(X)=0.8, \mu_A Low(X)=0.2$$

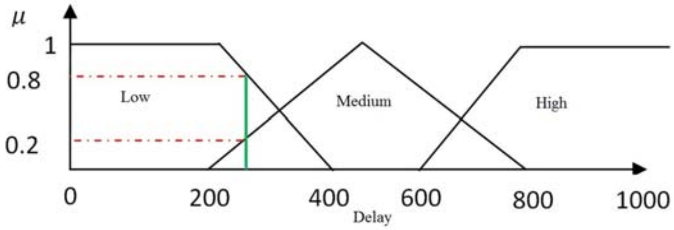

Figure 3- Membership graph for Delay.

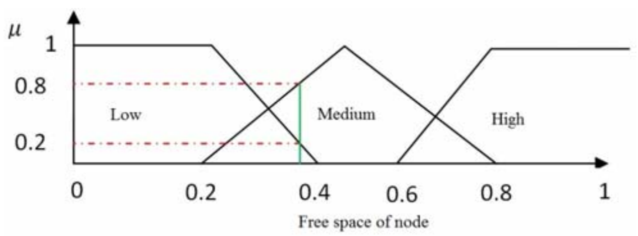

Figure 4- membership graph for FSN

C. The semantic similarity between resources and queries

The rate of semantic similarity between resources and queries is a parameter that with using it the process of resource discover and selection will be improved; the selection of the most adequate node will be done with more precision due to clustering of resources by their semantic content. By annotating resources some nodes that have similar resources can be identified and due to some problems the access to the desirable resource is restricted, some similar resources can be used instead and thus the fault tolerant of system can be increased. We define the availability of annotated resources, denoted as SSRQ, with the fuzzy set definition: {Low (L), Medium (M), and High (H)}.

To obtain the availability of annotated resources we use following equation [30] to calculate semantic similarity between resources. Here A is a node and B is a query, and their Ontology Sets are S (A) and S (B) respectively. We compute the semantic similarity between semantic query and annotated resources by equation 2.

$$Sim(A,B)=\frac{|S(A)\cap S(B)|}{|S(A)\cap S(B)|+|\alpha(A)\cap S(B)|+|\beta(A)\cap S(B)|} \quad (2)$$

Figure 5 shows membership graph for this parameter. For example consider a numeric input: 0.77 is a non-fuzzy number with the membership degree of 0 belongs to Low level, and with the membership degree of 0.3 belongs to Medium level, and with the membership degree of 0.7 belongs to High level.

It means:

$$\mu_A High(X)=0.7, \mu_A Medium(X)=0.3, \mu_A Low(X)=0.0$$

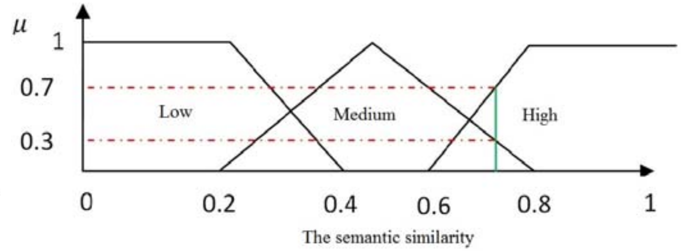

Figure 5- membership graph for SSRQ

D. The rank of being adequate

We use this parameter to classify rank of being adequate into five categories. The higher rank that a node gets, it is the more adequate node foe allocating resource. Figure 6 shows the membership graph for the rank of being adequate.

With using membership degree in above membership graphs, fuzzy inference rules will be created as follow in table 1. Fuzzy inference is a process that during it, mapping from inputs to outputs using fuzzy logic is regulated. Using a set of rules, each rule is weighted between 0 and 1 and then with mamdani fuzzy inference system and with T-Norm operator,

Table 1- Fuzzy rules which used in our scheme

Delay	FSN	SSRQ	Result
High	Low	Low	Very High
High	Low	Medium	High
High	Low	High	Medium
Medium	Low	Low	High
Medium	Low	Medium	Low
Medium	Medium	High	Low
Low	Low	Low	Very Low
Low	Low	High	Low
Low	High	Medium	Very High

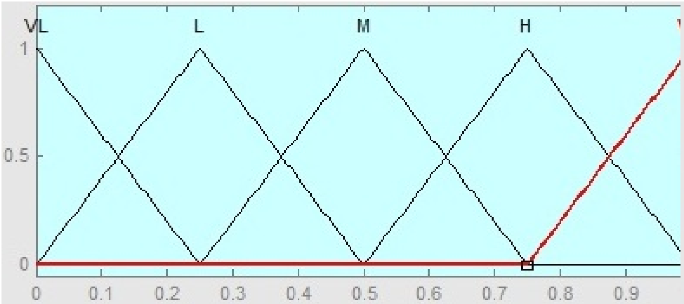

Figure 6- the rank of being adequate for each node to allocate resources.

output Fuzzy set will be cut. Since in inference system making decisions are based on the evaluation of all rules, somehow the rules must be combined. Figure 6 shows fuzzy inference for the first rule of table 1, and The same procedure is repeated for the other rules and then aggregation results that is obtained from each step is calculated for all rules and deffuzification phase will start. The input for the defuzziffication process is the aggregated output fuzzy set and the output is a single crisp number. Figure 7 shows Mamdani fuzzy inference system for the first rule.

Figure 8 shows rules of table with Hypothetical values in Matlab software. This figure shows that which rules must be fired and also how each member functions impact of the output result.

One of the Deffuzification operators is centroid operator which calculates the centre of gravity of shape. Centroid approach [31] is used to defuzzify the output. The overall centroid of N overlapping areas is given by equation 3.

$$\alpha = \frac{\int_Z \mu_A(x) z dz}{\int_Z \mu_A(x) dz} \qquad (3)$$

Where y is the domain value corresponding to rule *i*, *N* is the number of rules triggered in the fuzzy inference engine and $\mu(y)$ is the predicate truth for that domain value. The defuzzification process creates a centroid value that represents the rank being adequate for resource selection.

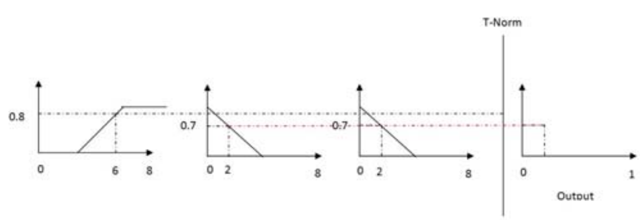

Figure 7 - Mamdani fuzzy inference system for the first rule

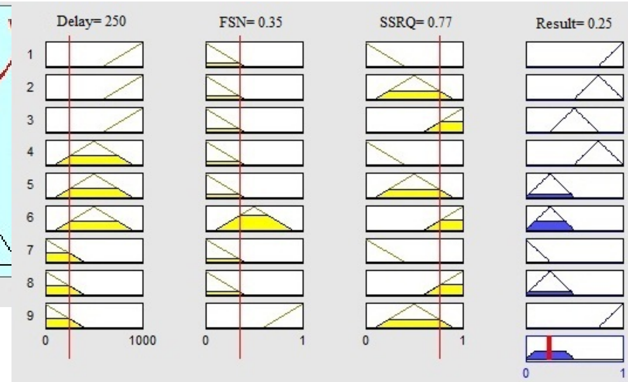

Figure 8- Fuzzy inference system using Matlab

V. PERFORMANCE EVALUATION

The homology of grid and p2p is sharing of resources. P2P grid is a specific kind of grid which causes the simpler resource management. Generally in p2p grid DHT is used because of its simplicity. [21, 24] are using DHT. [5] Is based on grouping and clustering the nodes and it is using hierarchical approach.

The hierarchical approach allows multilevel communities to create and arrange an optimum community size and an elastic searching space.

In our scheme several fuzzy parameters are used which one of them is the amount of annotated resources by ontology, so it supports semantic. For selecting a node, because the searches rule of Mamdani table and in parallel, the speed of selecting a node is very high and also it has a low delay. In our scheme the space of allocated resources is considered, so load balancing is very low and it reduced network traffic. Table 2 shows this point.

Now let us compare our scheme with other schemes in computational aspect. In some schemes like [21, 25] which they are using chord algorithm computational complexity is o (log n), but DHT may incur either a high traffic load for result intersection or large overhead for multiple publication and update.

In some schemes like [32], computational complexity is O (n). n is the number of nodes that are connected to RMS. In some schemes like [24], agent is used for resource management and also its computational complexity is O (n). In our scheme the order of computational complexity is O (1). Since, the fuzzy inference engine is used in the proposed approach, all the rules in the rule-base are processed in a parallel manner by the fuzzy inference engine. In this way the search is done in a parallel manner [17, 33]; thus, the computational complexity will be O (1). Table 3 shows this point.

Table 2our approach vs. exist approaches

	Several QOS	Semantic	Selection	Delay	Load Balance
Our approach	Support	Support	Very quick	Very Low	Very Low
[5]	Support	Support	Quick	Low	Very low
[21]	Not Support	Support	Slow	High	Low
[22]	Not Support	Support	Slow	High	High
[24]	Not Support	Support	Slow	Medium	Low
[25]	Not Support	Support	Quick	Medium	Very Low
[26]	Not Support	Support	Medium	Medium	High

Table 3 computational complexity of our approach vs. other approaches

	Our approach	[21, 25]	[24, 32]
computational complexity	O (1)	O (Log n)	O (n)

To simulate semantic characterizes on our proposed approach, we use GridSim simulator [34]. GridSim presents tools for the modelling and simulation of network features with different abilities. We add semantic features in some existing classes in Grisdim for enabling semantic simulation features. We evaluate the performance of our approach in terms of successful jobs and utilization of resources. We ran two experiments to compare the performance of our approach and a non-semantic resource management approach. We chose [35] which is a fuzzy based resource selection approach.

Fig. 9 exhibits the correlation between ratio of successful jobs and job query amounts for semantic and non-semantic situations. The consequence exhibits that some jobs are turned down under non-semantic occasion due to tight coupling between requesters' necessities and resources, because this is on the foundation of precise keyword selection. For high query rates, the job success chance will be decreased. For the semantic situation, rate of successful jobs is higher than non-semantic situation and high query ratios do not influence its performance. Fig. 10 exhibits the distinction in employment of resources between semantic and non-semantic situations.

In semantic situation, the employment of resources is clearly proportionate to the jobs query ratio. Therefore, the employment of resources in semantic situation is higher than that of non-semantic situation. It is due to semantic matching provides exact and precise matching.

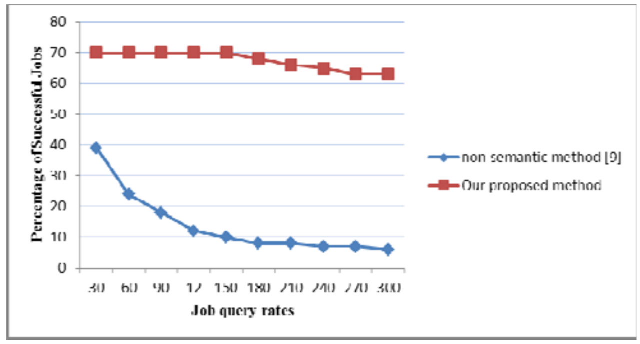

Figure 9 Percentage of Successful Jobs vs. Job query rates (per sec)

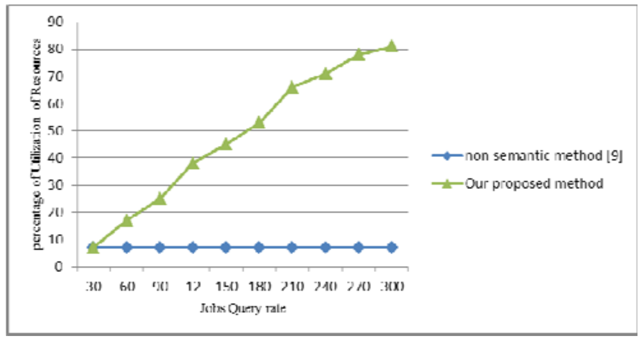

Figure 10 Response Time (seconds) vs. Jobs Query rate (per sec)

VI. Conclusion

This paper proposes an elastic forceful resource management approach which is able to give high QoS with lower resource management costs. Performance of a Grid system is based on an efficient resource management procedure. Therefore, there is a necessity for extensive resource management approach to decrease job refuse rate and to increase utilization of resources. In this paper semantic feature is used in conjunction with fuzzy theory in a centralized resource management approach and the performance of semantic and non-semantic situations is compared. The results of our experiments show that job success probability and utilization of resources improve with semantic approach. The results also confirmed the efficiency of the design in scalability, efficiency, robustness, delay, waiting time, response time and access time to resources.

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