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Resource Scheduling Based on Ant Colony Optimization Algorithm in Grid Computing Environments

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Abstract: Resource scheduling is a extremely complex problem in grid computing. The performance of Grid strongly depends on the efficiency of resource scheduling. But, resource scheduling needs more optimal resource scheduling algorithm, otherwise it increases the cost and completion time and decreases the resource utilization efficiency. To improve performance of grid computing and resource utilization efficiency, it is urgent to design an optimal resource scheduling algorithm. This paper proposes Grid resource scheduling algorithm based on ant colony optimization. The proposed algorithm can achieve optimized resource allocation policy based on the users' demand and improve the system's performance. The new resource scheduling algorithm is implemented and its advantages are investigated in the Gridsim simulator. The simulation results show that the application of resource scheduling algorithm based on ant colony optimization can effectively reduce total task completion time, balance the load of system well and improve the efficiency of resource scheduling.

Key words: Resource scheduling, grid computing, ant colony optimization, evaporation rate

INTRODUCTION

Grid computing is a hot field of research currently that have attracted a large number of scientist and company. It is expected that they will have a huge impact on many areas such as business, science, engineering and society (Jiang *et al*., 2011). Grid computing is a form of distributed computing which concentrates on providing remote computational resources sharing and acquisition, such as coordinating and sharing application, data, computing, storage, hardware and software resources (Jiang *et al*., 2011; Xie *et al*., 2010). It is a promising technology for future computing platforms (Xie *et al*., 2010).

In order to provide high performance and high-throughput computing, Grid computing needs realize resource sharing and collaborating from personal computers to supercomputers located around the world. However, there are all kinds of problems in grid resource management (Liang *et al*., 2011). Especially, grid resource scheduling is the important problems of researchers concern (Qu *et al*., 2011; Chen *et al*., 2011; Zhong and He, 2012). On the one hand, the Since resource availability varies in the course of job execution, Grid environment is highly dynamic in nature. On the other hand, in computational grid the resource users (consumers) have different requirements, while the resource providers have various goals and strategies. So resource scheduling is not only a complex working, but also is a potential challenge in Grid computing. A inefficient resource scheduling algorithm reduces the resource utilization efficiency and increases job's completion time. Hence, as important component of grid computing technology, the efficiency of resource scheduling directly influences the overall performance in grid computing environment. Recently, a lot of researches have been done for efficient utilization of resources.

In our paper, the proposed resource scheduling for Ant Colony Optimization (ACO) algorithm has considered characteristics of the grid computing, with which we can have a prospect of a view of such environments to efficiently allocate the users of appropriate resources for calculation. To take into account to all goals, including the network bandwidth, cost, reliability and timeliness, we set up four types of pheromone to guide the search behavior and search direction of each ant. The ACO algorithm integrates with an adaptive scheme to modify the value of four parameters which decreases the variance of the entire search process the up to now most interesting explored transitions probabilistically bias future search, avoiding ant to waste resources in not promising regions of the search. The experimental results demonstrate that the our resource scheduling for ACO algorithm not only adapts to the dynamic grid environment, but also enhances the entire performance in grid computing environment. Furthermore, the new scheduling algorithm balances the load and supports various computing intensive applications which makes the resource schedule scalable and flexible.

RELATED WORK

The resource scheduling in grid computing environment is a NP complete problem. A relatively new approach to problem solving takes inspiration from the social behaviors of animals, such as ants, birds and bees. Especially, it is known as Ant Colony Optimization (ACO) which is the general purpose optimization technique (Bonabeau *et al*., 1999; Dai *et al*., 2009). ACO is a paradigm for designing metaheuristic algorithms for combinatorial optimization problems. Dorigo *et al*. proposed the first ant colony algorithm (Dorigo *et al*., 1991). It has been proved to solve both static and dynamic combinatorial optimization problems efficiently. A recent approach is the use of ACO algorithm for resource scheduling in grid computing environment. Recently, there has been an increasing interest in resource scheduling based on ACO algorithm .

In order to minimize the total tardiness time, adapt the dynamic grid environment and improve the the entire performance of the system, an ACO algorithm for dynamic resource scheduling in grid computing was proposed (Lorpunmanee *et al*., 2007).

A new algorithm based on an echo intelligent system, autonomous and cooperative ants was addressed (Salehi and Deldari, 2006). According to present environmental condition, ants can commit suicide and procreate to balance the load. Correspondingly, the algorithm improves the performance of the mechanism.

Goyal and Singh, presented ant colony algorithm based on the load balancing to improved utilization of resources (Goyal and Singh, 2012). In the proposed algorithm, the pheromone is directly relevant to resources. The increase or decrease of pheromone represents load and relies on task status at resources.

Kokilavani and Amalarethinam, proposed Ant Colony Optimization based on sharing the load which enhances the resource utilization and number of tasks scheduled and decreases the whole response time (Kokilavani and Amalarethinam, 2012).

Chang *et al*. presented a job scheduling based on Balanced Ant Colony Optimization algorithm in the Grid environment that minimize the completion time of a given set of jobs (Chang *et al*., 2009)

Xu and Gu, suggested that the structure of Grid makes the Quality of Service (QoS) of Grid more difficult than network and distribute computing environment. They proposed a category scheduling based on ant algorithm that makes use of user category, resource category and task category. The algorithm proposed by them improved the successful scheduling rate, system performance and QoS to a certain extent (Xu and Gu, 2009)

Nasir *et al* proposed an enhanced ant algorithm for balancing the load in grid computing environments. According to job characteristics and resource capacity, the best resource is allocated to the jobs. At the same time it balances the entire resources (Nasir *et al*., 2010)

In order to meet the complex needs of resource scheduling in grid environment, a dynamic resource scheduling algorithm based on ACO algorithm is proposed. In this paper, the designed scheduling algorithm shares the load among the resources for optimizing the resource usage in the grid environment. Furthermore, we take account into scheduling finite resources to meet the various users need for QoS. Our experimental results show the effectiveness of the designed algorithm.

PROPOSED SCHEME

The basic structure of resource scheduling algorithm: Resource scheduling in Grids is complex due to heterogeneousness of computing resources, resource management policies, users' requirements in grid computing environments. Moreover, users and owners are independent of one another and have different access policies, scheduling strategies and objectives. In order to achieve high system optimization performance and make the users' tasks be allocated to the most suited resources, the basic structure of grid resource scheduling algorithm is designed for three-layer model, respectively, i.e., application layer, grid middleware layer and grid resource layer. The overall structure of grid resource scheduling algorithm is shown in Fig. 1.

The grid resources layer is the lowest layer in the basic structure and the foundation of the entire system. It includes hardware resources (e.g., computers, storage systems, sensors) and software resources (e.g., applications and experts).

The middleware layer is the core of resource scheduling. It is in charge of grid dynamic resource scheduling and offers services to grid applications with most suited computing resources. According to users' need, the grid middleware layer searches the available resource in the resource layer and return the most suitable resources to the user.

The application layer is the highest layer in the basic structure which provides applications service to resource user, such as science, engineering and business.

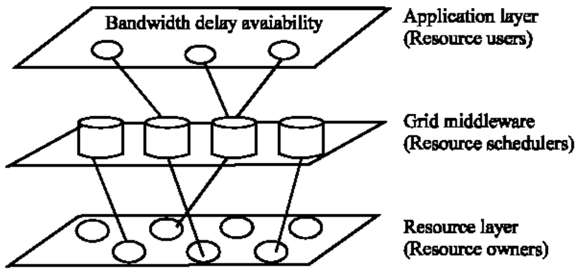

Fig. 1: The basic structure of grid resource scheduling algorithm

The task classification based on Qos: In order to maximum grid system throughput and satisfy the users' needs with the available computing resource, the grid resource scheduling need to consider the users' Quality of Service requirements, the requirements types and users' behaviors, costs and risks impact of timeliness. According to the users' requirements, QoS parameters are given as below:

- **Network bandwidth:** To accomplish the grid computing task, network bandwidth has to be take into account. It is is one of the key factors affecting the performance of system. The high bandwidth communication should satisfy users' priority bandwidth requirements and provide high bandwidth to user
- **Timeliness:** In order to meet users' requirements in time, it need accomplishes all the tasks in the shortest period of time and timely respond to the user's submission of task. It provides several timeliness parameters, such as the total time, the start time, the deadline and other parameters. In addition, we define the new timeliness parameter, namely the expected execution time. It is to predict the current run time using the previous resource performance
- **Reliability:** In order to complish a great deal of complex users' tasks, it need offer a stable and reliable performance support for grid computing environments. When a long running task occurs a failure during its execution, the task will be restarted, in turn leading to a poor performance and wasting time and resources. Therefore, to reduce the adverse effects of failures, the reasonable degree of reliability need be set up for users' tasks
- **Cost:** User is concerns of task cost which is relevant to the execution of grid tasks. It includes the two parts of computation resource cost and bandwidth resource cost
- Different resources demands may require different QoS. To establish the quantitative evaluation of different standards, it defines the different QoS parameters to measure the user's satisfaction

Grid resource scheduling algorithm based on ant colony optimization: The ACO Algorithm for resource scheduling in grid computing aims at mapping submitted tasks to appropriate resources according to the processing ability of tasks and the characteristics of the tasks. The proposed grid resource scheduling algorithm based on ACO is composed of five sections that are achieving task requirements, creating an ant for a user's task, calculating and storing the initial pheromone for all the resources, assigning task to the suitable resource with the highest pheromone value, as well as update global pheromone update after finishing the processing task. With the algorithm based on ant colony, we can successively allocate the suitable one or several resources to the user's task until meeting the needs of the users.

For each task, the scheduler will record the needed network bandwidth, cost, reliability and timeliness. Each submitted task needs different data transmission time and computation time for completion. An ant represents a task in the grid computing environments. The system creates an ant for every task and the ant move from one to another resource to evaluate the initial pheromone value for all the resources. The initial value of pheromone is estimated according to the network bandwidth, cost, reliability and timeliness of a given task when assigned to this resource defined by:

$$\Gamma_{ij}(0) = a_1\Gamma_{ij}t(0) + a_2\Gamma_{ij}b(0) + a_3\Gamma_{ij}r(0) + a_4\Gamma_{ij}c(0) \quad (1)$$

where, $\Gamma_{ij}(0)$ is the initial pheromone value for task j assigned to resource i. $a_1+a_2+a_3+a_4 = 1$, $0\leq a_1+a_2+a_3+a_4 \leq 1$, $a_1+a_2+a_3+a_4$ denote the weight assigned to execution time, network bandwidth, cost and reliability, respectively.

$$\Gamma_{ij}t(0) = 1/(T_j / T_{min}) \quad (2)$$

$$\Gamma_{ij}b(0) = 1/(B_j / B_{min}) \quad (3)$$

$$\Gamma_{ij}c(0) = 1/(C_j / C_{min}) \quad (4)$$

$$\Gamma_{ij}r(0) = R_j / R_{max} \quad (5)$$

where, C_j is the cost associated with the execution of a given task j and B_j is the network bandwidth to fulfill a given task j, T_j is the execute time needed of task j, R_j is the reasonable degree of reliability for a given task j. C_{min} is the minimum cost associated with the execution task, B_{min} is the minimum network bandwidth to fulfill grid task, T_{min} is the execute time needed of grid task, R_{max} is the maximum reasonable degree of reliability for grid task.

The initial value of pheromone reveals the capacity of each resource to process a particular task, while resource selection will solve the scheduling problem by selecting the most suitable resource to process the user's task.

Any ant may choose its resource randomly and by calculating the special probability function according to Eq. 6:

$$p_{ij}(t) = \begin{cases} \dfrac{[\tau_i(t)]^\alpha [\eta_i]^\beta}{\sum_{u \in K_j} [\tau_u(t)]^\alpha [\eta_u]^\beta} & i, u \in K_j \\ 0, \text{otherwise} \end{cases} \quad (6)$$

where, ηi is the I nherent properties of resources, namely the innate performance quantity of the resource i ($\eta_i = \Gamma_{ij}(0)$), $\tau_i(t)$ represents the concentration of pheromone of resource i at time t. α denotes the importance of pheromones, β represents the importance of intrinsic properties of resources, $p_{ij}(t)$ is probability of task j to select grid computing resources i. K_j is collection of resources list for the task j can be performed on the grid.

Pheromone updating mechanism will solve the load balancing problem of the resources. The modified ACO algorithm need to adjust the basic pheromone updating rule for the original ACO algorithm. We can change the pheromone intensity on the node by adopting a local update strategy to reflect the changes of the pheromone in time. The updating pheromone is executed as follows:

$$\tau_i(t+1) = g * \tau_i(t) + (1-g)\Delta\tau_1 \quad (7)$$

where, $\Delta\tau_1$ is additional pheromone when task moves from scheduler to resource. g refers to evaporation rate, it is given by:

$$g = [(V/U) * 0.45^n * (V/U)] + 0.05 \quad (8)$$

where, V and Uare the number of resource and task, respectively. n is given by:

$$n = \sqrt[3]{(V/U) - 1} \quad (9)$$

The dynamic value of the evaporation rate will ensure that ant will move faster as the number of task increases.

SIMULATION RESULTS

The resources scheduling in such large-scale distributed system is a complex working. Experiments are conducted to evaluate the performance of the proposed algorithm based on ACO in terms of resource utilization efficiency, the time and costs of accomplishing tasks and the evaporation rate effect on resource utilization.

The proposed resource scheduling algorithm is implemented in Gridsim toolkit which is one of the most popular and perfect simulation tools for the grid environment. Hence, we select Gridsim toolkit. It can provides basic functions for the simulation of the different environments of heterogeneous resources, users and application models. Additionally, it also offers the service of the creation application tasks, matching tasks with resource and their management. Adopting Gridsim toolkit, the new scheduling algorithm can be used in grid management resources.

In this experiment, we change the number of tasks in the Grid computing system to compare completion time of our resource scheduling algorithm to other resource scheduling algorithm under various the numbers of tasks in the Grid system. The time is measured in time units. The time unit is 1 ms.

Compared with other two resource scheduling algorithm, task execution time under the different size of computing task for the proposed resource scheduling algorithm is illustrated in Fig. 2. The case 1 allocates better CPU capabilities than network capabilities to the grid task, the case 2 uses the traditional ant colony algorithm and the case 3 uses our algorithm.

Figure 2 indicates that the effectively works of proposed algorithm is larger than that of the other two resource scheduling algorithm. The time taken to complete

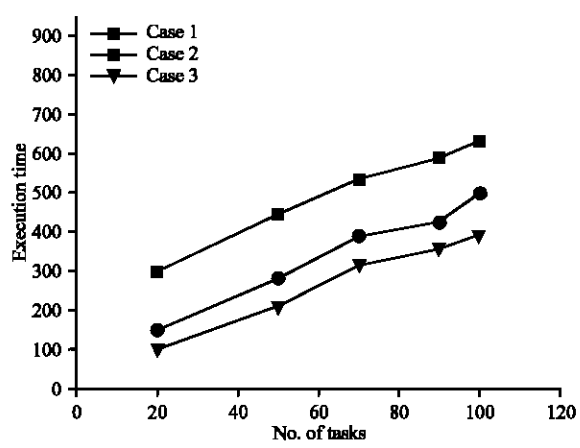

Fig. 2: Number of computation tasks effect on execution time

20 tasks, 50 tasks, 70 tasks, 90 tasks and 100 tasks for the case 3 are lesser than that for the case 1 and case 2. The resource scheduling based on ACO algorithm which is based on the colony behavior increases the performance in resource discovery in the dynamically changing grid environment.

According to the above performance comparisons, some conclusions can be drawn. In most of the test cases, the resource scheduling based on Ant Colony Optimization algorithm is more efficient than the cases 1 and 2 to allocate grid resource in test application. As the number of computing tasks and size of transfer data increase, there are more merits to use our algorithm to schedule grid.

CONCLUSIONS

The grid computing environment is more promising area in this internet era which needs to be upgraded in all fronts to reap the benefits. Hence, the efficiently resource scheduling algorithm is a crucial for grid computing to satisfy users' requirements and the large-scale heterogeneity and dynamics present in the distributed resources. The grid resource scheduling based on ACO algorithm is proposed. The algorithm is to match takes with suitable resources and balance the load, resulting in improved utilization of resources. Experimental results showed that the our proposed resource scheduling algorithm performs better than other resource scheduling algorithm, including resource utilization efficiency, the time and costs of accomplishing tasks. It makes the resource schedule scalable and flexible.

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