Grid Computing based on Game Optimization Theory for Networks Scheduling

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Abstract—The resource sharing mechanism is introduced into grid computing algorithm so as to solve complex computational tasks in heterogeneous network-computing problem. However, in the Grid environment, it is required for the available resource from network to reasonably schedule and coordinate, which can get a good workflow and an appropriate network performance and network response time. In order to improve the performance of resource allocation and task scheduling in grid computing method, a game model based on non-cooperation game is proposed. Setting the time and cost of user’s resource allocation can increase the performance of networks, and incentive resource of networks uses an optimization scheduling algorithm, which minimizes the time and cost of resource scheduling. Simulation experiment results show the feasibility and suitability of model. In addition, we can see from the experiment result that model-based genetic algorithm is the best resource scheduling algorithm.

Index Terms— Network security; Grid computing; Workflow scheduling; Resource allocation; Game theory

I. INTRODUCTION

In order to solve complex problems in limited time, the concept of grid computing is introduced and becomes an alternative supercomputer program. A variety of computing resource is used by virtual connection, while ability and structure of this resource have the great difference from each other [1]. The goal of grid computing is to develop a simple and effective computing platform for a variety of devices [2]. Network response time and performance in grid environment is often more than that in non-grid environment, which requires us to carefully design plan, scheduling, coordination of network resource [3]. Since these resources have to work together in grid environment, parallel and multi-level calculation is used to solve these problems [4]. According to the dynamic changes of network environment, the resource of scheduling becomes very complicated. The user and resource can enter or leave grid at any time, which lead to dynamic changes of grid system [5]. Therefore, a fast effective resource scheduling algorithm is desperately required [6].

The resource scheduling algorithm must balance the reliability, usability, cost of resource and the quality of user’s service. Grid computing could involve businesses and tasks form multiple business provider. Therefore, grid computer system must use free resources and assign resources from different business providers into the tasks of different users [7].

Recently, a large number of grid resource scheduling algorithms are proposed to solve these problems, such as genetic algorithm, ant colony algorithm and game theory algorithm [8]. In this paper, game theory algorithm is adopted to handle resource scheduling in grid environment. Game theory is a major method used in mathematical economics and business for modeling competing behaviors of interacting agents. When two or more participants with different objectives must be selected, the game theory can be used to analyze the problem. The decision made by one participant can affect another participant in this case. The game relationship between resource provider and user always exists, where they all have a reasonably advantageous settlement.

A game model based on non-cooperation game is proposed to perform workflow scheduling, where the resource agents in network environment are the participants from game model [9]. These participants compete against each other for maximizing their profit and designing scheduling algorithm. In addition, incentive agent uses an optimal algorithm to process workflow scheduling, which minimizes the time and cost of resource scheduling.

The rest of this paper is organized as follows. In Section two, grid computing model and the proposed model parameters are introduced and analyzed deeply. The game strategies and corresponding parameter are described in Section three. The experimental results are shown and Nash equilibrium is also analyzed in Section four, and the conclusion is made in Section five.

II. SYSTEM MODEL

The grid computing model and non-cooperation game model are introduced in this section. Firstly, we introduce grid computing model. Then, we analyze the game theory model used by grid computing model.

A. Grid Computing Model

Grid computing model is shown in Figure 1, the respective workflows are firstly passed to resource agents which acts as standardized interfaces to entities in the cluster ecosystem. Then, the resources scheduling is performed by resource agents. In order to meet user
budget and the deadline requirement, any scheduling algorithm is used to perform user resource scheduling, where scheduling algorithm we should adopt is mainly based on the user profit and running cost [10]. After the workflow scheduling strategy is selected, resource agent will assign workflow to the corresponding resource [11][12], and then be allocated to user until the workflow is over. By introducing utilization function, incentive resource agent can optimize the workflow scheduling. The adopted scheduling algorithms in this paper include random-based algorithm and genetic algorithm.

![Figure 1. Grid computing model](image)

**B. Game Model**

In the proposed game model, resource agents are participants, which they compete and co-operate with each other for maximizing their profits, while the purpose of resource scheduling is to minimize the time and cost of running workflow. These adopted notations in this paper are shown in Table 1.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D$</td>
<td>The maximum time in workflow</td>
</tr>
<tr>
<td>$B$</td>
<td>The maximum profit in workflow</td>
</tr>
<tr>
<td>$C_{\text{min}}$</td>
<td>Minimum profit of resource agent</td>
</tr>
<tr>
<td>$U_{\alpha}$</td>
<td>Utilization function of resource agent</td>
</tr>
<tr>
<td>$U_{\text{bg}}$</td>
<td>Utilization function of resource agent when using random-based algorithm.</td>
</tr>
<tr>
<td>$U_{\text{gc}}$</td>
<td>Utilization function of resource agent when using genetic algorithm.</td>
</tr>
<tr>
<td>$P$</td>
<td>Profit of resource agent</td>
</tr>
<tr>
<td>$T$</td>
<td>Real execution time in workflow</td>
</tr>
<tr>
<td>$C$</td>
<td>Execution cost in workflow</td>
</tr>
<tr>
<td>$C_{\text{rk}}$</td>
<td>Scheduling cost of resource agent</td>
</tr>
<tr>
<td>$C_{\text{bg}}$</td>
<td>Scheduling cost of resource agent when using random-based algorithm.</td>
</tr>
<tr>
<td>$C_{\text{gc}}$</td>
<td>Scheduling cost of resource agent when using genetic algorithm.</td>
</tr>
<tr>
<td>$C_{\text{e}}$</td>
<td>Executed cost of resource agent when using random-based algorithm.</td>
</tr>
<tr>
<td>$C_{\text{r}}$</td>
<td>Executed cost of resource agent when using genetic algorithm.</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Weight of workflow run-cost in utilization function</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Weight of workflow runtime in utilization function</td>
</tr>
</tbody>
</table>

Table 1. Explanation of Notation

In order to reduce the cost and time in running workflow, utilization function is introduced, as shown in the following Equation [13][14]:

$$U_{\alpha} = P - C_{\text{bg}} - C_{\text{rk}}$$

where, $P$ is a profit function, as shown in Equation 2:

$$P = C_{\text{min}} + \alpha(D - T) + \beta(B - C)$$

where, $\alpha$ and $\beta$ are positive number decided by customer service quality. If the cost and time of workflow has the same priority, we can get $\alpha = \beta$, which can be viewed as protocol between user and resource agent. The purpose is to improve the solution so as to increase the profit of resource agent. In order to avoid negative, the lower bound is defined as $C_{\text{min}} = C_{\text{bg}} + C_{\text{rk}}$. In other words, if random-based algorithm is adopted by resource agent, the lower bound is defined as $C_{\text{min}} = C_{\text{bg}} + C_{\text{rk}}$. In addition, if genetic algorithm is adopted by resource agent [15][16], the lower bound is defined as $C_{\text{min}} = C_{\text{bg}} + C_{\text{rk}}$.

Users exchange with each other the respective workflow runtime and cost related to scheduling information after entering the grid computing environment. According to the information, the appropriate $\alpha$ and $\beta$ can be determined in the algorithm. After the two values are transferred to resource agent, the algorithm deems the two values still remain the same in the process of game.

The detailed steps of proposed algorithm are described from the user's perspective as follows [17, 18].

Users send their workflow to resource agent;

Users receive $C$ and $T$ from resource agent;

The optimal solution in workflow is winner of the Game;

According to these parameters of utilization function and resource agent, compute the cost of workflow, and then pay a payment to winner [19];

Wait for the next round.

According to user budget and the deadline requirement in workflow, the resource agent must select an appropriate strategy. The detailed steps of proposed algorithm are described from the perspective of resource agent as follows [20-22].

Resource agent receives a workflow;

Resource agent selects an appropriate strategy, according to the utilization function and the scheduling case;

Return $C$ and $T$ back to users;

If users agree the setting of the two values, the workflow tasks will assign resource to run the workflow, and then receive the payment from user and pay the resource cost of resource provider;

If users refuse the setting of the two values, wait for the next round.

### III. SELECTION OF GAME STRATEGY AND PARAMETER

#### A. Game Strategy

Resource agent can select two scheduling strategies, including random-based algorithm and genetic algorithm. Genetic Algorithm is an effective tool to solve the problem of complex system optimization, which is suitable for mixed nonlinear planning problems with dispersed variables. Non-dominated sorting genetic
algorithm (NSGA-II) is one of the most effective algorithms to solve multi-objective optimization problems [23-24], so the algorithm is adopted in this paper.

Resource agent randomly selects the resource in random-based algorithm until an appropriate solution is found so as to meet user budget and the deadline requirement in workflow. The solution may not be optimal, but it can decrease the time and cost of algorithm, so in some cases the resource agent will use the method to perform workflow scheduling [25] [26].

B. Determine $\alpha$ and $\beta$

Based on the Equation (1) and Equation (2), we can get utilization function, as shown in Equation (3).

$$U_B = C_{\text{min}} + \alpha(D - T) + \beta(B - C) - C_{\text{RES}} - C_{\text{BK}}$$ (3)

As for random-based algorithm and genetic algorithm, the utilization functions can be written as follows, respectively.

$$U_{\text{BR}} = C_{\text{min}} + \alpha(D - T_B) + \beta(B - C_R) - C_R - C_{\text{BR}}$$ (4)

$$U_{\text{BG}} = C_{\text{min}} + \alpha(D - T_G) + \beta(B - C_G) - C_G - C_{\text{BG}}$$ (5)

If $U_{\text{BG}} > U_{\text{BR}}$, resource agent will use genetic algorithm to schedule the workflow, so we can get as the following equation.

$$\alpha(T_B - T_G) > (C_G - C_R)(1 + \beta) + C_{\text{BG}} - C_{\text{BR}}$$ (6)

In addition, if $T_B - T_G > 0$, we have

$$\alpha > \frac{C_{\text{BG}} - C_{\text{BR}} + (C_G - C_R)(1 + \beta)}{T_B - T_G}$$ (7)

If $T_B - T_G < 0$, we can get

$$\alpha < \frac{C_{\text{BG}} - C_{\text{BR}} + (C_G - C_R)(1 + \beta)}{T_B - T_G}$$ (8)

When $\alpha = \beta$, if $T_B - T_G > 0$ is hold, we have

$$\alpha > \frac{C_{\text{BG}} - C_{\text{BR}} + C_G - C_R}{T_B - T_G + C_R - C_G}$$ (9)

If $T_B - T_G < 0$ is hold, we have

$$\alpha < \frac{C_{\text{BG}} - C_{\text{BR}} + C_G - C_R}{T_B - T_G + C_R - C_G}$$ (10)

Given $A = \frac{C_{\text{BG}} - C_{\text{BR}} + C_G - C_R}{T_B - T_G + C_R - C_G}$ and $\alpha > A$, and assume the solution of genetic algorithm is better than that of random-based algorithm, there are three possible resource-agent strategies:

If $\alpha > A$, resource-agent adopts genetic algorithm;

If $\alpha < A$, resource-agent adopts random-based algorithm;

If $\alpha = A$, resource-agent randomly select scheduling algorithm.

When $\alpha > A$, incentive resource-agent adopts genetic algorithm, but a larger $\alpha$ will increase the cost of users, while incentive agent of users will be decreased, so it is necessary for resource-agent to select an appropriate $\alpha$.

As for any $\alpha$, let’s assume it is a positive value.

IV. SIMULATION EXPERIMENTS AND ANALYSIS

The performance of the proposed workflow scheduling algorithm is evaluated by simulation in grid computing environment. Some situations are taken into account in simulation; the probability of winning is given in multi-player game and two-player game. In addition, we also analyze Nash equilibrium and the effect of all the parameter $\alpha$ on winning probability. Simulation parameters are shown in Table 2.

TABLE II. SIMULATION PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D$</td>
<td>90000</td>
</tr>
<tr>
<td>$B$</td>
<td>900000</td>
</tr>
<tr>
<td>$C_{BR}$</td>
<td>1000</td>
</tr>
<tr>
<td>$C_{BG}$</td>
<td>100000</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>1.3</td>
</tr>
</tbody>
</table>

A. Analysis of Winning Probability in Two-Player Game

Assume only two resource-agents take part in game, the game result is shown in Figure 2.

![Figure 2. The probability of winning when RB1 adopts random-based algorithm and RB2 adopts genetic algorithm](image)

The abscissa denotes the game round, while the ordinate denotes winning probability of resource agent. The RB1 adopts random-based algorithm, RB2 adopts genetic algorithm. As you can see from the above figure, the winning probability of RB2 is 80%, while the winning probability of RB1 is 20%. The result is shown in Figure 3 when both of game participants adopt genetic algorithm.

You can see from Figure 3 that their winning probability is approximately equal when both of game participants adopt genetic algorithm to perform the scheduling, which is consistent with our expectations. According to the results of Figure 2-3, we can derive the pay-off matrix of the game, as shown in Table 3.
It can be seen that genetic strategy is dominant algorithm, which they tend to reach (0.5, 0.5). In addition, both of game participants adopt genetic algorithm to perform the scheduling. Since strictly dominant strategy must be a Nash equilibrium, this causes two-player game has Nash equilibrium $S^*=(\text{genetic strategy, genetic strategy})$ [27]. Therefore, all the rational players will select genetic algorithm to perform the workflow scheduling. It can be seen that our proposed game model eventually drive the resource agent uses the genetic algorithm.

Likewise, the probability of winning in multi-player game is similar. If all of game participants adopt genetic algorithm to perform the workflow scheduling in multi-player game, winning probability of each participant would converge to $1/n$ [28].

### C. Influence of Winning Probability in User Budget And Deadline Requirement

The goal of the proposed game model is to reduce the time and cost of user resource scheduling in paper. We will analyze the effect of user budget and deadline requirement on winning probability in the process of game, as shown in Figure 5.

![Figure 5. Search domain in random-based algorithm and genetic algorithm](image)

B denotes user budget and D denotes user deadline. The dotted box denotes a solution space when the cost and time of resource scheduling is very high. The solid box denotes is a solution space when the cost and time of resource scheduling is very low. In addition, the curve denotes the optimal solution of genetic algorithm. The Figure shows that the search domain of random-based algorithm or genetic algorithm will decrease when user budget and deadline requirement are very low. As for resource agent, comparing with the solution of random-based algorithm, the solution of genetic algorithm is the closer to the optimal solution. With the increase of user budget and deadline requirement, the solution space of genetic algorithm also will be decreased, which can improve the process of search so as to make winning probability close to 0.8 when $\alpha$ is more than 0.9. In this case, resource agent will explicitly adopt genetic algorithm to perform the resource scheduling, where the value can be viewed as guarantee value.

![Figure 4. Winning probability in different $\alpha$](image)
the found solution is the closer to the optimal solution. Figure 6 shows the winning probabilities under the different budget and deadline, where the $\alpha$ is shown in Table 2.

![Figure 6](image-url)  
**Figure 6.** Winning probability of resource agent in user budget and deadline requirement.

It can be seen that winning probability of winning probability of random-based algorithm is higher when solution space is limited. With the increase of search space, the probability of bad solution searched by random-based algorithm will increase, while winning probability of random-based algorithm is decreased.

D. Influence of User Budget and Deadline on the Selection of $\alpha$

This section mainly analyzes the influence of user budget and deadline requirement on the selection of $\alpha$, the experiment result is shown in Figure 7.

![Figure 7](image-url)  
**Figure 7.** Influence of user budget and deadline on the selection of $\alpha$

According to the above analysis, it can be seen that the solution of using random-based algorithm is fairly similar to the solution of using genetic algorithm when user budget and deadline requirement are relatively low, as shown in Figure 7. Therefore, if the network requires the genetic algorithm is adopted to get an optimal solution, users need to select a larger $\alpha$ so as to prompt resource agent to use genetic algorithm.

V. CONCLUSION

With the development of the Internet technology, the Internet has offered boundless networks resources. Grid computing is to use these network resources to solve complex computational problems. Nevertheless, resource diversity leads to the network heterogeneity, which makes the task scheduling becomes very difficult. In order to improve the performance of resource allocation and task scheduling in grid computing method, a game model based on non-cooperation game is proposed. Setting the time and cost of user’s resource allocation can increase the performance of networks, and cause resource agent to use an optimization scheduling algorithm, which minimizes the time and cost of resource scheduling. Simulation experiment results show the feasibility and suitability of model. In addition, we can see from the experiment result that model-based genetic algorithm is the best resource scheduling algorithm.

REFERENCES


