The Workflow Task Scheduling Algorithm Based on the GA Model in the Cloud Computing Environment

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***Abstract*—Taking advantage of the resource sharing, the cloud computing service mode save the investment cost efficiently.In a cloud computing environment, the workflow task scheduling algorithm is based on the task processing time and the execution cost factors and start point of the user demand for quality of service, in good user experience and the biggest economic benefits both made significant breakthrough. As a result, the workflow task scheduling algorithm based on GA model in the cloud computing environment improve the system performance greatly, and it is the effective ways to meet the user's QoS requirements.**

***Index Terms*—cloud computing, workflow, task scheduling, algorithm**

I. Introduction

Cloud computing as a new computing model[1], is integrated in a network of huge computational resources to a very large scale resource pool.It is an on-demand service mechanism to users.From a certain perspective, it is not only an academic concept but also a business concept[2] .Cloud computing provides users with a kind of advanced resources and service interaction patterns [3, 4], it offers a variety of computing and resource service effectively and conveniently,for example, storage ,server resources and network application services such as electronic commerce.

To reasonable use of the resources of cloud computing service mode, maximum cost savings, get rid of the limit time and region, the workflow tasks are executed in cloud computing environment.Workflows are a series of automated tasks or business activities joined each other. The workflow in the cloud computing environment is called cloud workflow. At present, a lot of kinds of task scheduling algorithm in the workflow management in grid environment[5-8].The application's execution time is greatly reduced by these algorithms that improved the efficiency of application execution certainly. however, making use of workflow model in cloud computing environment is sure to follow the business model of cloud computing and consider the cost in the execution of the workflow. Under paying in cloud computing mode, users don't always use the high quality of service resources in order to complete the task fastly and early, but would prefer to use the services that can meet the demand and require less service to reduce the service costs. How to satisfy user's QoS at the same time in cloud computing environment, as far as possible making use of resources efficiently. Therefore it is great significant to design a good workflow task scheduling algorithm.

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II. Related Works

Based on the two restricted conditions which are the given deadline and budget related QoS of the users, the workflow task scheduling algorithm is designed in cloud computing environment. From the user perspective the algorithm guarantees to meet the deadline under the condition of budget, at the same time to meet the needs of the user's budget under the condition of the deadline. Based on the objective, a kind of improved GA based (Genetic Algorithm) modeling of workflow task scheduling Algorithm is designed in order to achieve the optimum solution to meet the users needs, to meet a better user experience, essentially implement service-oriented resources principle based on cloud computing.

In order to achieve the above goal, this article will do related research from the following several aspects:

（1） The task's deadline and user's budget are the optimimal goals of the cloud workflow task scheduling algorithm.
（2） Based on the workflow task characteristics of the cloud computing GA modeling to calculate the of the genetic factors.
（3） The algorithm make use of simulation tools CloudSim to simulation experiment。

Because of existing the GA algorithm can't satisfy the workflow task scheduling optimization in the cloud computing environment, this paper puts forward a new type of modified GA algorithm that for chromosomes should not only indicate the service resource label that the workflow task assignment, but also need to indicate the sequence on the server that the workflow task is executed.

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Using a two-dimensional string to represent the chromosomes scheduling method is designed, according to the deadline and budget limit to set goals, the fitness function to constraint fitness evaluation method also is designed.

III.THE WORKFLOW TASK SCHEDULING ALGORITHM DESIGN IN THE CLOUD PLATFORM

A.The Workflow in the Cloud Platform

Workflow refers to the automatic operation of the part or in whole in the process of business, focus on delivering information or business from more than one user according to certain rules .In short, the workflow is a set of mutual communication activities or tasks to run automatically

In order to make full use of the cloud resources in the cloud computing, the resource advantages of the service mode are cost savings largely, getting rid of time geographical limitations. The workflow task excuting over the cloud is called a cloud workflow task, this task has the following advantages

- Workflow using a variety of cloud resources promote the execution of the workflow task;
- The cloud computing platform provides the elastic application mode that has the resource sharing and on-demand features,it can greatly save the hardware overhead of the workflow task execution;
- Cloud platform for user mode increases the user's satisfaction, make the execution of workflows friendly;
- The uncertainty of workflow execution sequence make use of business model in cloud computing platform that can greatly save the workflow task's execution cost。

B.The Workflow Task Scheduling Algorithm

The workflow task scheduling algorithm focuses on the issue that mutual penetration associated tasks is mapped to a variety of different service resources modules to deal with. This mapping relations belong to the "NP hard problem" [9], there is no specific algorithm to the optimal solution. And now workflow task scheduling algorithm is roughly divided into two categories [10]: the scheduling algorithm based on the best-effort and the limit service scheduling algorithm based on QoS. However, the scheduling algorithm is designed for the single task's workflow and the purpose is how to reduce the execution time of the task carried out in relatively simple environment. In cloud computing environment, the workflow task is relatively dense which in parallel execution, Because of service application or competition failure frequently, the user's execution time and execution cost of two typical QoS qualifications must be considered. Therefore, based on the comprehensive consideration, a kind of improved GA model workflow task scheduling strategy is designed that considering user's QoS requirements of for cloud computing environments on the basis of two kinds of scheduling algorithms.

C.The Algorithm Representation

Literature[11] on the current workflow task scheduling algorithm to do a comprehensive analysis and summary, this paper use predecessor DAG diagram to express the algorithm's structure, with Γ to show the task's $T_i(1 \le i \le n)$ finite set, Z is directed edge (T_i, T_j)set, T_i is the parent of the task T_j, on the other hand, T_j is the children of the task T_i. Subtasks can be conducted after all the parent tasks execution . If m present the total number of service resources that are available, the resources used to excute task T_i is $S_i^j(1 \le i \le n, 1 \le j \le m_i, m_i \le m)$.A task can only be run on each resource. Each resource has ability to handle different tasks and the costs are also different. If t_i^j is the sum of processing time and total time for data transmission that the service resource S_i^j excute task T_i, c_i^j is the sum of the service price and the price for data transmission that the service resource S_i^j excute task T_i. With D、B respectively express the workflow execution deadline and budget costs. As a result, the entire workflow applications are used the two triples $\Omega(\Gamma, Z, D)$、$\Omega(\Gamma, Z, B)$to express. The task T_{entry} is entrance task that has no parent task, and the task T_{exit} is exit task that has no subtasks .

This paper research goal is that the workflow task scheduling maps a task T_i into the most appropriate service resources S_i^j, at the same time, guarantees the deadline D and budget B are as minimal as possible.Usually a viable workflow task scheduling algorithm must satisfy the following conditions:

- Task can only excute after the ancestors of all the tasks performed;
- Each task appear only once in the process of scheduling;
- Each task can be allocated a available execution time to complete tasks sucessfully.

D.Genetic Algorithm

Genetic algorithm is a robustness search method according to the theory of evolution, it can be found a relatively high quality solution in a large search space. This solution's goal is that the new individual combine each other in the given optimal solution space and the not search solution space to iterative search.Using chromosome individuals to represent the search space of feasible solutions, the fitness function values determine the chromosome degree of the population space.Combination of typical GA algorithm with the cloud computing environment, we will elaborate the workflow task scheduling algorithm from the following several aspects in this paper.

1) Initialization of the population. population composed of randomly generated chromosomes individuals
2) Using the genetic operation to produce the next generation of population; For each individual chromosome to do fitness evaluation
3) Repeatedly 1) 2) until the algorithm satisfies the stop condition.

(1)Chromosome coding

Populations of each individual use chromosome coding to the feasible solution of a problem. Each chromosome consists of four elements in a vector to represent the task allocation. These four elements are: taskID , serviceID , startTime, endTime . In this paper the chromosome encoding ignores time frame to simplify the process to the operation of the genetic factor.Only use each task assigned service number and the corresponding mission number to chromosome coding and then performs crossover and genetic variation operation.Making use of the chromosome of timestamp will be optimized string as a workflow task scheduling scheme.

T0 T1 T2 T3 T4 T5 T6 T7

S1-- S2-- S1-- S3 -- S3-- S4-- S4-- S1 Entity 1

S2-- S4-- S2-- S4 -- S1-- S3-- S1-- S4 Entity 2

Figure 1 A simple workflow chart of DAG

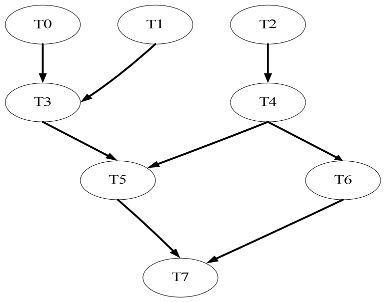

Figure 2 One-dimensional string express entity

Figure 1 is a simple DAG workflow diagram, figure 2 is corresponding with the scheduling code using one-dimensional string representation. It is not a correct workflow in workflow scheduling. In task scheduling process, each individual child task only can excute after the parent task completion and some independent tasks can be performed on the corresponding service resources at the same time, such as the T3 and T4 in figure 1. The sequence of task excution in a workflow diagram has a decisive effect on the performance of the entire process, therefore, chromosome coding string according to the characteristics to design conside task resource mapping relationship, also have to consider the priority of the execution sequence .Figure 2 represent a simple string encoding scheme, it is to put the task in fixed order, and then, allocate service resources in sequence, but it did not reflect their execution order.For example in entity1, T3 and T4 are need S3 resource and S3 resources can only be assigned to one task. Therefore, task allocating resources correctly must also specify the task execution sequence.

Using a two-dimensional string to resolve the above problems, as shown in figure 3, one dimensional string is resource symbol, another is the task execution sequence on resources. Then put two-demensional string into one-dimensional chain to operate, they are shown in figure 3 below, the one-dimensional string number representate the label of resources.

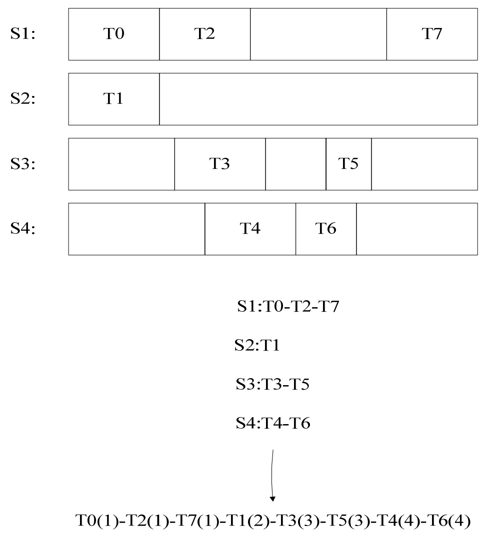

Figure 3 Two-demensional string express entity

(2)Initialization of population

Initial population of entities are generated by the random heuristic, each entity scheduled by task must follow the rules:

1) Task ti was choosed which the parent task has been scheduled.

2) Ti's preparation time calculated by the formula $readyTime(T_i) = \max_{T_j \in P_i} endTime(T_j)$, the Pi is the Ti 's parent task set.

3) A service resources Si randomly selected from the executable task Ti resource.

4) Computing the transTime(Ti) which is the data transfer time from the input to output deviece from the parent task to service resource Si.

5) Calculating available timestamp which Si service after the task of startTime (Ti) , $startTime(T_i) = ready(T_i) + transTime(T_i)$

6) Randomly assigning a timestamp to Ti。

(3)Fitness function

Fitness function is the function that is based on optimizing target to evaluate the degree of the population individual. In this paper, the algorithm's goal is to minimize costs and execution time, so it will be divided into the cost of fitness function and time fitness function to measure. Among them, using the binary variables α and β to define these two functions. If the algorithm have the time limit condition, then

$\alpha = 0, \beta = 1$. If the algorithm have cost qualification, then $\alpha = 1, \beta = 0$.

Having time constraints in the fitness of the scheduling, encourage the low cost of individual groups to iteration, the individuals preferred the earliest finish time in genetic algorithm into the next generation. For the time constraints and priorities to meet the time constraints of the individual to form. It's time fitness function are defined as follows:

$$F_{time}(I) = \frac{t(I)}{D^{\beta} \times \max Time^{(1-\beta)}} \tag{1}$$

t (I) is the individual finishing time, maxTime is the population maximum completion time, D is time budget of the workflow.

With cost budget constraint of scheduling and priority to meet the constraint of the optimization solution formed, its the cost fitness function of the individual are defined as follows:

$$F_{\cos t}(I) = \frac{c(I)}{B^{\alpha} \times \max Cost^{(1-\alpha)}} \tag{2}$$

C (I) is the sum of the individual task execution costs and data transmission costs. $c(I) = \sum_{T \in I_i} c_i^k, 1 \le k \le m_i$, maxCost is the highest cost and B is the budge of the workflow.

The formula (1) and (2) merged into a final fitness function (3):

$$F(I) = \begin{cases} \alpha \times F_{\cos t}(I) + \beta F_{time}(I), if F_{\cos t(I)} > 1 or F_{time}(I) > 1, \\ F_{\cos t}(I)^{\beta} \times F_{time}(I)^{\alpha}. otherwise \end{cases} \tag{3}$$

Fitness function value smaller the individual solution is better. If the value of $F_{time}(I)$ and $F_{\cos t}(I)$ are greater than 1, individuals execution time and execution cost are more than the predetermined goal, the entire value of F (I) the value will choise the value of the $F_{time}(I)$ or $F_{\cos t}(I)$. The individual iterative will be reduced. Otherwise, individual execution time and execution cost will be within the budget scope.With time constraints, if scheduling time within the permission, then according to the execution cost to evaluate the individual, execution the less the cost of fitness is better .If the cost is within the budget, according to the execution time to evaluate the individuals. The execution time is smaller, the better the individual fitness

(4)Genetic operation

Selection operation: after evaluation of the fitness function, all individuals of the populations will be classified based on their fitness function value. The performance which fitness function values are small is more optimal, will be held to the next generation populations evolve.

Crossing operation: is the operation that recombining the current population individuals to a new one that is more optimal[12]. As shown in figure 4, the crossing operation process are: (1) randomly select two individuals as the parent body. (2) in the first of the parent body dispatch randomly select two points in the array. (3) all tasks in the middle of the two dots as the continuous intersection. (4) swap the task location of all the intersections on the parent body. (5) the two paternal offspring are produced by a new combination of the parent body. From figure 4, the children body 1 inherited tasks T0, T2, T4 and T6 from the parent body 1, inherited tasks T1, T7,T3 and T5 from the parent body 2; The children body 2 inherited the task T7 ,T1, T3 and T5 from the parent body 1, T1, T3, T5, inherited tasks T0, T2, T4, T6 from the parent body 2. Crossing is the process that exchanged the service resources between the same task in the parent body.

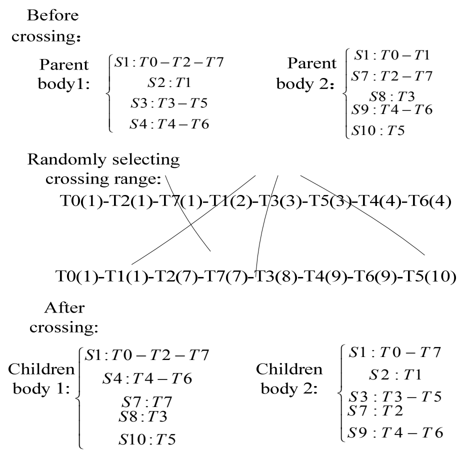

Figure 4 Crossing

Variability:, the offspring has the differnet features of the parent with the mutation at a certain probability in the genetic algorithm. The exchange and alternative mutation made the genetic algorithm to search a new genetic material in order to a greater exploration space

Exchange variation is changed the executing sequence of the tasks with the same service resources, the implementation process is as follows: firstl, randomly select a service id.Then exchange the resource location of the two separate tasks randomly. The exchange mutation is shown in figure 5, the task T0 and T7 has made exchange in the same resource S1, T7 has as the initial execution time frame.

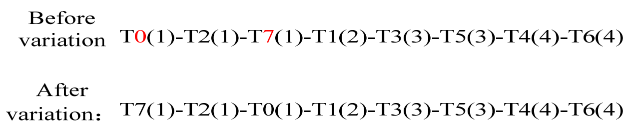

Figure 5 Exchange variation

Alternative variation is to reassign the task to resource. The operation steps as follows: first, randomly select a task and then, choose an alternative from alternative service resources of this current task's resource. Alternative variations are shown in figure 6, we will classify the service resource to A, B, C three categories, different tasks require different services to perform. The following figure, T0, T3, T4 need A, B, C resources to perform , service T2 choosed A is to mutation operation, service resources T2 of the A clategory randomly selected S6 to assign task for alternative variations.

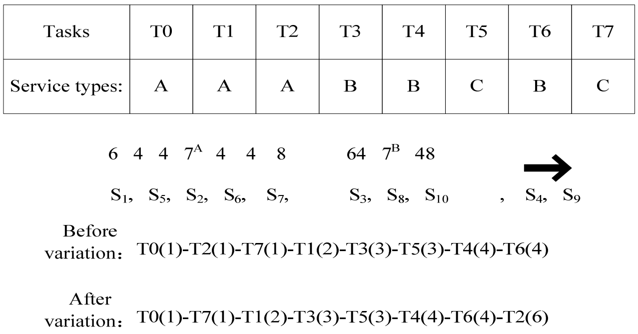

Figure 6 Alternative variation

(5)The distribution of timestamp

After the crossing and alternative mutation operations, as the above operations ignore the distribution of the time frame, the offspring substring is not a string of scheduling can be used .In this paper, the task performed on each service use the timestamp to assigned the execution time.As shown in figure 7, you can query the available timestamp and assign a specified timestamp according to the allocation info of the resources and the executing sequence of tasks produced by the GA algorithm.

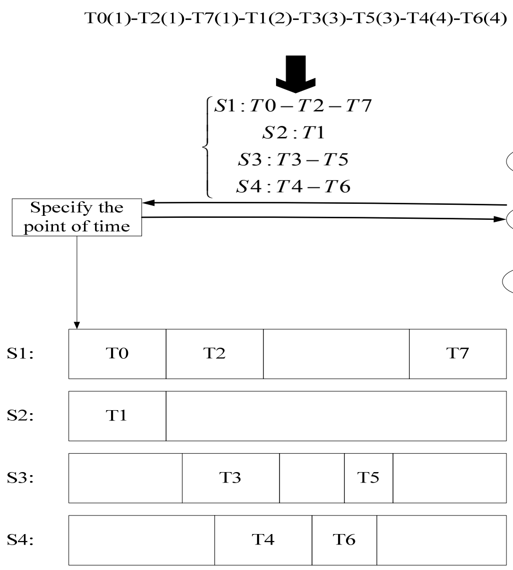

Figure 7 The distribution of timestamp

IV.EXPERIMENT

A.Experimental Envireonment

In this paper, task scheduling simulate experiment with experimental tools CloudSim in cloud environment. Shown in the figure 8 the simulation environment of communication flow diagram. Fistly DataCenter request service to CIS cloud data center. Every service can query task's timestamp ,also can leave request and submit their mission.

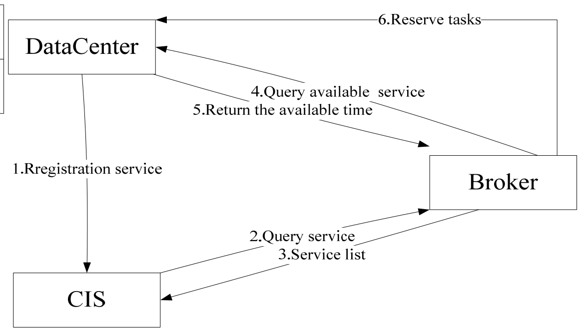

Figure 8 Simulation of communication trafic

In simulation experiment, there are 15 different types of services, each service has a different price, each type of service has 10 different service provider. The ouptut data of each task in scientific workflow is its subtask's input, as a result, data processing is the process that data flow out from task processing nodes to its subtask processing nodes. The I/O scope of scientific workflow is [10M, 1024M]. The topology of the service resources are connected. At the same time, the cost of task processing and transmission is inversely proportional to its processing and transmission time. The scheduling algorithm is be measured with the time and execution cost of the workflow, the task limiting execution time is used to determine whether the algorithm of scheduling within the deadline, the limiting execution cost used to judge whether to meet budget constraints.

To more rational execution limiting time and cost budget, this paper draws on the result of time optimal algorithm (HEFT) and cost optimal algorithm (GC) . HEFT algorithm pursue the best service and the minimum execution time in a heterogeneous environment[13]. GC algorithm's goal is to minimize workflow execution cost by using the lowest price resources service. C_{HEFT} and C_{GC} respectively mean the implementation costs of the HEFT algorithm and GC algorithm, T_{HEFT} and T_{GC} respectively mean the time sum total of HEFT algorithm and the GC algorithm . The limiting experiment time is:

$$D = T_{HEFT} + k \times (T_{Gc} - T_{HEFT}) \tag{4}$$

Budget constraint is：

$$B = C_{GC} + k \times (C_{HEFT} - C_{Gc}) \tag{5}$$

The 0,0.5 and 1 of k's value mean the performance in high、medium、low three condition.Default parameter is settings for: population is set to 10, choice probability is 0.6, crossing probability is 0.1, exchange mutation andalternative variation are 0.1 and 0.01, evolutionary value is 100.

B.Analysis of Experimental Result

In order to better evaluate the performance of the GA algorithm, this paper has used the literature [14] [15] two non GA heuristic scheduling algorithm for comparison, cost greed - time distribution scheduling algorithm (TD) and time greed-distribution scheduling algorithm (CD). TD algorithm solve the time constraints problem, CD algorithm solve the cost constraint. First, the optimal solution is produced by random initial population and genetic operation, then the optimal solution of the CD algorithm and TD algorithm combine with the random solutuion iteratively to the final scheme. CD and TD mean the optimal solution of CD and TD, GA means the optimal solution of the genetic algorithm randomly generated initial population, GA + CD and GA + TD said TD and CD algorithm's initial population of genetic algorithm.

This paper also standardize the execution time and execution cost. C_{value} and T_{value} say the perform cost and time consumption.To budge constraints $C_{value}|B$ standardize the perform cost, $T_{value}|T_{HEFT}$ standardize the perform time.After standardization if meet the budget,the perform cost will not grater than 1, it is easy to distinguish whether meet the restrictions. In the same way, for the time limitation, $T_{value}|D$ and $C_{value}|C_{GC}$ say the standardization of the execution time and cost distribution.

(1)The time optimization under cost constraint

According to the formula (4) (5),after setting B, parameters 0.5 0 and 1 respectively mean high,medium, low hree levels. Using the GA, CD, GA + CD three scheduling methods to task schedul for the balance neuroscience workflow and not balance protein workflow. The cost and time budget are shown in figure 9 below. This figure show that the GA and CD algorithm cannot meet the low budget constraints, only the combining CD with GA and the CD algorithm result used in the initial populations of GA can be optimize the result. Therefore, the combination of the two GA + CD algorithm can guarantee the lowest cost under the same time optimal values.

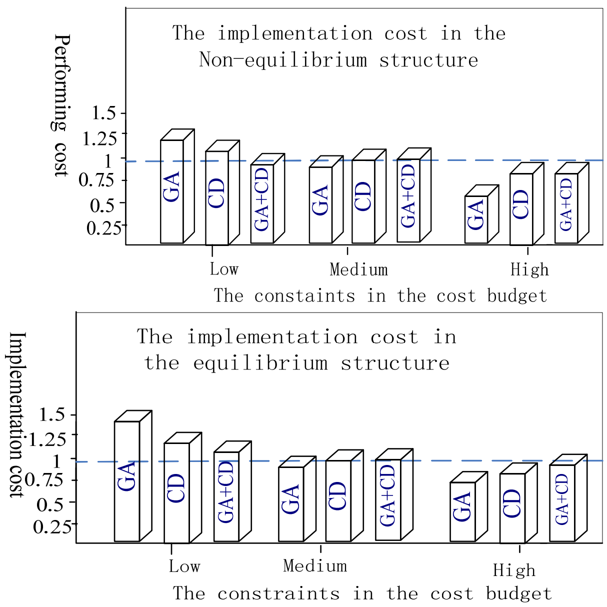

Figure 9 Implementation cost comparison results under the cost constraints

(2)The cost optimization under time constraints

When setting deadline condition D, according to the formula (4) (5), the parameter k's value 0,0.5 and 1, respectively, using the GA, TD, GA + TD three scheduling to schedul experiments for the balance structure workflow and non-equilibrium workflow. Experimental structure is shown in figure 10. Under the lower time limit, the GA and TD algorithm are difficult to meet the conditions .In the same limit condition, the GA + TD can be overall improved performance. In the non-equilibrium applications ,as the deadline of restrictions improved, under the same deadline, TD algorithm cost lower, and TD is superior to the GA algorithm. For balancing structure applications, the GA and TD algorithm's results are roughly the same under moderate limit. For the unbalanced structure, the GA + TD algorithm solved the problems perfectly. In the higher degree of time constraints, the TD is closer to the optimization algorithm of the minimum consumption cost consumption values than the GA algorithm, and the execution time of non-equilibrium structure is relatively short.

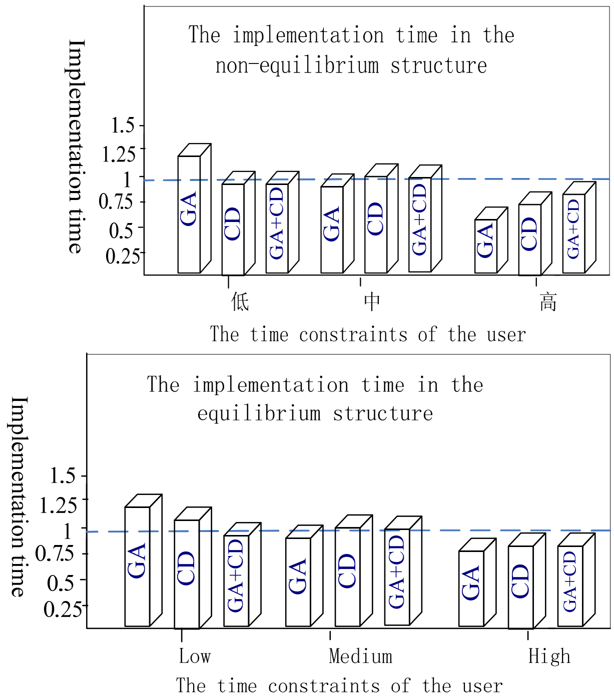

Figure 10 Implementation time cost comparision results under the time constraints

(3)The influence of algebra operation

This paper also sets the cost budget is 3000 yuan, by changing the algebraic operation of GA algorithm to adjust the entire workflow performance changes. As shown in the figure11.12 ,the first to the fifth generation's execution costs close to the budget. As the figure can be seen, the execution time rapid increased due to cost reduce .In the same way, execution cost decrease quickly make the execution time increase rapidly.As shown in the figure below, once the GA algorithm found a task indivitual in budget, the performance will be improved, the iteration process can reduce the execution time correspondingly]16].

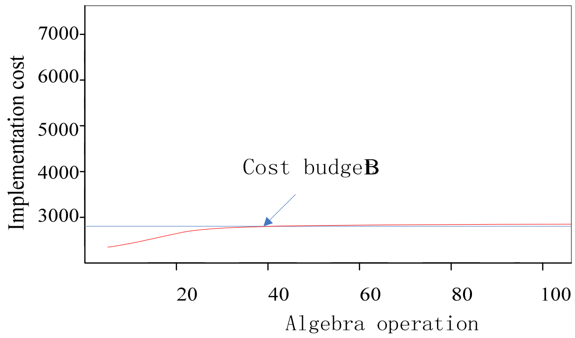

Figure 11 The implementation cost within the 100 generations

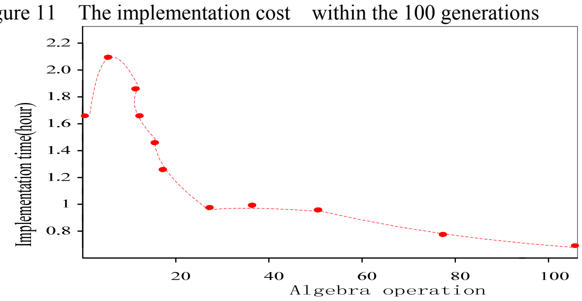

Figure 12 The time implementation within the 100 generations

(4) The influence of the initial population

Under the 3000 yuan conditions, observing the performance of the algorithm by changing the size of the initial population changes. Figure13, 14 as follows ,when the population size is small, the scheduling algorithm can not satisfy the budget limit. As the scale increases, greater than 5, increasing the size has no impact on implementation costs. when a given population is larger, scheduling algorithm can quickly find the optimal solution and shorter execution time at the same cost budge[17,18].

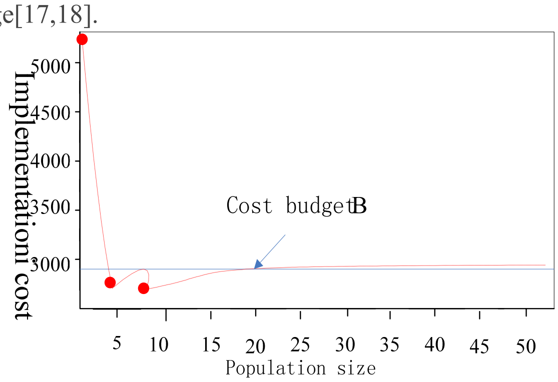

Figure 13 The influence of the 3000 population size to the cost

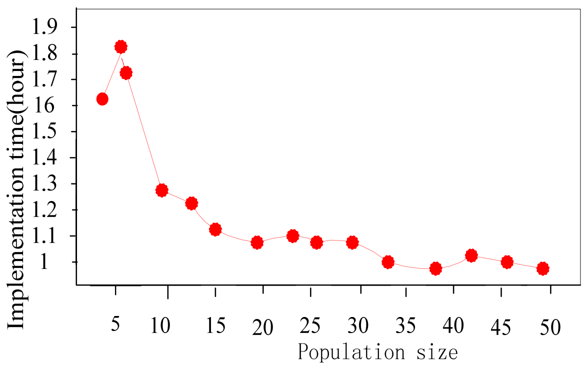

Figure 14 The influence of the 3000 population size to time

V.CONCLUSION

After integrated the advantages and disadvantages of various algorithms, the proposed workflow task scheduling algorithm based on the GA model in the cloud computing environment can fulfill the goals of the workflow task scheduling. Combination with characteristics of task scheduling under cloud computing environment, reasonable design genetic factors, will be applied to scientific workflow instances. In Cloudsim environment simulation, figure 11 show that within 100 generations the execution cost of the final experiment, from two aspects of time and cost consumption, the proposed algorithm's performance has improved perfectly analysis from algebra and the population size under the different settings, improved the efficiency of task scheduling, which can maximum satisfy the QoS requirements of the users.

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