A Secure and Efficient Cloud Resource Allocation Scheme with Trust Evaluation Mechanism Based on Combinatorial Double Auction

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Abstract

Cloud computing is a new service to provide dynamic, scalable virtual resource services via the Internet. Cloud market is available to multiple cloud computing resource providers and users communicate with each other and participate in market transactions. However, since cloud computing is facing with more and more security issues, how to complete the allocation process effectively and securely become a problem urgently to be solved. In this paper, we firstly analyze the cloud resource allocation problem and propose a mathematic model based on combinatorial double auction. Secondly, we introduce a trust evaluation mechanism into our model and combine genetic algorithm with simulated annealing algorithm to increase the efficiency and security of cloud service. Finally, by doing the overall simulation, we prove that our model is highly effective in the allocation of cloud resources.

Keywords: Cloud resources allocation, secure service, trust model, combinatorial double auction

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1. Introduction

Cloud computing is currently the mainstream way to provide network services, it provides customers with a flexible, dynamic web services using virtualization technology. International Data Corporation (IDC) predicts that the developments speed of cloud computing will be much faster than that of original IT industry, according to the estimate, cloud computing can achieve twenty-six percent annual increase [1]. IDC also predicts that more and more large enterprises will begin to set up their own cloud centers, which will become the main target on the construction of the next generation data center.

Many researchers have predicted "the core competition in the future lies in the cloud data center," Cloud data center[2] is the concentration of equipment data resources, meanwhile, it also provides energy for data computing and equipment maintenance, etc. Cloud data center can be a separate construction. Moreover, it can be distributed in multiple systems which are located in different areas. Cloud resources are gathered and provide services through multi-tenancy mode for different customs. The cloud resources are distributed physically, but in the prospective of users, they turn out to be a single entity logically .The resource management technology[2] in cloud data center is the core of cloud computing applications and the key technology of energy conservation and emissions reduction.

Cloud computing completes user's different tasks through service model [3], but for the users themselves, the management of computing resources is transparent. Users pay for the service they need, and then obtain what they desire from cloud services provider. This reduces users' consumption on buying cloud computing infrastructure, and enables them to focus more on the services they are interested in. Therefore, choosing the appropriate resource provider is critical.

The cloud resource management algorithm can draw lessons from grid computing and distributed computing, Based on the characteristics of cloud resource management, researchers have developed many different scheduling policies. Resource management problem is a NP-hard problem, many of the existing heuristic algorithm can achieve linear optimal. Until now, many theories based on algorithmic game theory have been proposed, these theories solve the problem of resource optimization in network system in the prospective of users. However, there exist many security threatens in the cloud computing services, consequently, the how to guarantee the information security of the cloud resource allocation is urgently to be solved.

To better solve the problems discussed above, in this paper, we propose a secure and efficient cloud resource allocation scheme with trust evaluation mechanism based on combinatorial double auction. Specifically, we introduce a trust evaluation mechanism into our model and combine genetic algorithm with simulated annealing algorithm to increase the efficiency and security of cloud service. Finally, by doing the overall simulation, we prove that our model is highly effective in the allocation of cloud resources.

The rest of paper is organized as follows: Section 2 introduces some related work to our research. In section 3, we propose a cloud resource management model based on combinatorial double auction and introduce a new algorithm SAGA to solve the winner determination problem in the cloud resource allocation. In section 4, we introduce a trust mechanism to the resource allocation model in order to encourage the healthy developments in cloud resource market. We do our simulation in section 5 and conclude our paper in the section 6.

2. Related works

Cloud resource management system integrates storage resources, computing resources, network bandwidth resources and other resources which belong to different organizations or individuals together, and couple these resources as a single integrated resource which can be provided to the user. Subsidiary resource management platform will then assign certain resources to complete users' tasks according to their own demands. Due to different management models may cause differences in scalability, stability and other performance, therefore the right choice resource management model, is one of the key to the success of cloud computing technology[4]. Appropriate management of cloud computing model can encourage owners to share resources, can make consumer have a fair and suitable access to resources, which can promote the development of cloud computing platform.

Weinhardt C in [5] proposed a cloud framework model. He pointed out the commercial application of the most widely pricing or pay on demand. At the same time, it also illustrated the main companies, such as Amazon, Google, Microsoft and other companies. These companies charge according to the need of consumers.

Yeo in the [6] analyzed the pros and cons of charging fixed prices as compared to variable prices and highlights the importance of deploying an autonomic pricing mechanism that self-adjusts pricing parameters to consider both application and service requirements of users. Based on these, they proposed an automatic pricing algorithm. Mihailescu M in [7] presented a dynamic pricing scheme suitable for rational user's requests containing multiple resource types. Using simulations, they compared the efficiency of the proposed strategy-proof dynamic scheme with fixed pricing, and showed that user welfare and the percentage of successful requests is increased by using dynamic pricing[8]. In [9] proposed a dynamic auction mechanism to solve the allocation problem of computation capacity in the environment of cloud computing. Truth-telling property held when they apply a second-priced auction mechanism into the resource allocation problem.

ShangS in [10] proposed a cloud market framework for people to build a uniform and fully competitive cloud market where users can buy resources from different companies and exchange their idle resources in a more flexible way. Then they defined a double auction Bayesian Game-based pricing model (DABGPM) for the suggested cloud market and discussed how to develop an optimal pricing strategy for this model. Zaman S in [11] formulated the problem of virtual machine allocation in clouds as a combinatorial auction problem and proposed two mechanisms to solve it. They performed extensive simulation experiments to compare the two proposed combinatorial auction-based mechanisms with the currently used fixed-price allocation mechanism and revealed that the combinatorial auction-based mechanisms can significantly improve the allocation efficiency while generating higher revenue for the cloud providers.

As is mentioned above, the model of double auction solves the problem of monopoly in cloud resource allocation but it can only auction a single type of resource and the efficiency is low. On the contrary, combinatorial auction model [12] can auction multiple types of resources at the same time but may lead to the damage of interest of one side. Combinatorial double auction (CDA), as the combination of the combinatorial auction and double auction, is a new way of auction which combines different types and amount of resources together according to both bidders' and sellers' demand. Compared to other auction mechanisms CDA guarantees the equality of status for both sides and increases the efficiency of the whole auction process.

Xia M et al in [13] proposed an improved combinatorial double auction model and solved the winner determination problem to maximize social welfare. Parnia Samimi et al in [14] proposed a market model called the Combinatorial Double Auction Resource Allocation (CDARA). The proposed method was economically efficient and motivated the participants to reveal their true valuation during bidding.

Xu in [15] proposed a cloud computing resource allocation model based on combinatorial double auction mechanism for more effective resource utilization. It can satisfy both user and provider requirements and it can generate higher revenues. The proposed method maximized the profit of cloud resource provider. However, it failed to offer a platform for the mutual negotiation between user and provider, which damages the benefit of user.

Zhao et al in [16] proposed a multi-round combinatorial double auction mechanism to allocate resources in geo-distributed data centers for big data stream processing. The QoS level was taken into consideration. In addition, the multiple rounds mode was adopted, so the failed users and data centers had the chance to adjust bids and asked to participate next auction round, increasing the ratio of successful transactions. However, the proposed method did not take the trust of participants into consideration. There may exist malicious users and service providers. The proposed method failed to offer a virtuous trade environment, and result in waste of cloud resources.

3. The algorithm of combinatorial double auction cloud resource management

3.1 Cloud resource management model based on combinatorial double auction

The existing cloud resource management center has not fully guaranteed the choice of double auction, which leads to the result of sacrificing the benefits of one side during the progress of auction. Meanwhile, for all of the cloud resource provider, the type of resources they can provide is roughly the same. Although all the resources are virtualized in cloud computing, they are transparent and making no difference to users. But for service providers, the different cost of the resource’s maintenance, storage location, etc. lead to different management fees for the same type of resource.

Fig. 1 shows our cloud resource management model based on combinatorial double auction. This structure consists of consumers, resources service agents, an auctioneer and resource providers. in the Cloud Resource management which is geared to the needs of the market, there are two main members, one is the Cloud Resource providers (Cloud Resource Provider, CRP), the other is the Cloud Resource consumers (Cloud Resource Consumer, CRC), usually the Cloud Resource consumers through the Cloud Resource agents (Cloud Resource Agent, CRA) ACTS as its representative, do all the work. The cloud resource consumers and providers use different strategies to realize their respective purpose. The auctioneer plays an important role in the model. Auctioneer sets the rules of the auction and the cloud resource consumers and providers have to obey the rules which are made by the auctioneer. In the cloud resource management, the main auction steps are as follows:

(1) CRP offer an price to auctioneer;

(2) CRA send their bidding documents to the auctioneer;

(3) The auctioneer determines an allocation scheme according to the corresponding strategy;

(4) The CRP and CRA which have completed the allocation task can negotiate with each other using SLA protocol about the performance requirements;

(5) If the coordination is successful, the auction ends; otherwise, the auctioneer will choose another CRP, until no CRP can be chosen to complete CRA’s task.

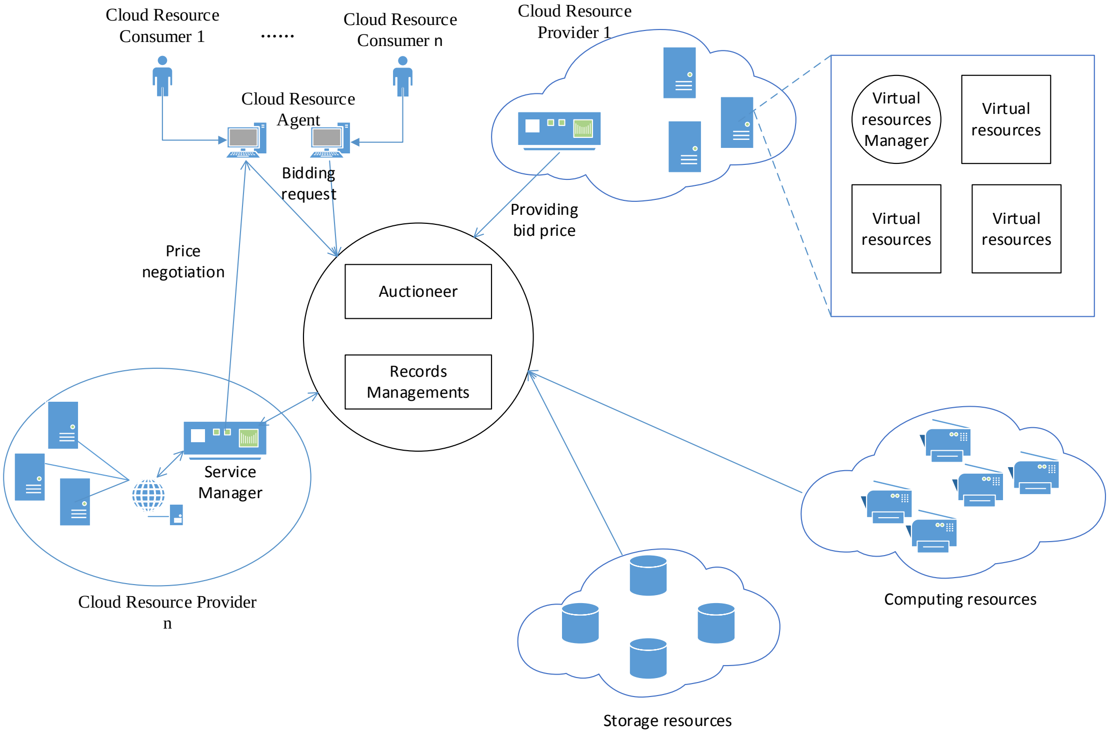

Fig. 1. Secure cloud resource management model based on combinatorial double auction

3.2 Problem description

The key problem in combinatorial auction is the winner determination problem. During the process of auction, buyers and sellers submit their bidding documents to the auctioneer which contains the amount of resources needed, as well as the price [7] of the resources.

The auctioneer integrates the bidding documents and chooses the best allocation scheme under the condition that amount of items provided by sellers exceeds the amount of items needed by buyers.

In the process of the auction, we assume that there are m buyers and n sellers bidding on k different types of cloud resources. Then the number of participants involved in the auction is N and $N = n + m$.

Definition1: Define vector $\vec{a}$ as the resources combination packages which is provided to users by the cloud resource providers. The package of participant j is marked as $\vec{a_j} = (a_{1j}, \cdots a_{ij})$,$a_{ij}$ represents the amount of type i resource that participant j has submitted.

If $a_{ij} > 0$,then j is user, he requires type i resource and the amount is a_{ij}.If $a_{ij} < 0$,then j is cloud resource provider ,he provides type i resources and the amount is a_{ij}.

Definition2: Define p_j as the total quoted price that participant j offered for all of his resources.

If $p_j > 0$,then it means bidding price. If $p_j < 0$, then it means auction price.

Definition3: Define matrix B as the set of participant's bidding items, B can be represented by $B = \{B_1, B_2 \cdots B_j \cdots B_n\}$, participant$j$'s bidding document can be represented as $B_j = \left(\vec{a}_j, p_j\right)$.

Consequently, the auctioneer can describe the problem as the following model (formula 3.1-3.3):

$$max \sum_{j=1}^{N} p_j x_j \tag{3.1}$$

$$s.t. \sum_{i=1}^{N} a_{ij} x_i \leq 0, \forall i \in I \tag{3.2}$$

$$X = [x_1, \cdots x_n], x_i \in \{0,1\}, \forall j \in \{1, \cdots, N\} \tag{3.3}$$

In the above formula, x_j stands for the result of allocation. If participant j wins the bid, then $x_j = 1$, else $x_j = 0$. Formula 3.1 is an objective function, formula 3.2 is a constraint function, and formula 3.3 simplifies the problem into a 0-1 programming issue. This model maximize the social surplus under the condition that resources supply exceeds demand. Consequently this problem is a 0-1 programming problem and a NP-hard problem.

3.3 The pricing determination model

We assume at the moment t,user i submits the a resources combination package $\overrightarrow{a_i}$, cloud resource management center can predict the current system load according to the following formula 3.4-3.6:

$$load_t = \frac{user\_amount}{proviede\_amount} \tag{3.4}$$

$$user\_amount = \sum_{i=1}^{N} \sum_{j=1}^{K} \left| \omega_j \, a_{ij} \right| \tag{3.5}$$

$$provide\_amount = \sum_{h=1}^{N} \sum_{j=1}^{K} \left| \omega_j \, a_{hj} \right| \tag{3.6}$$

In the formula, $user\_amount$ stands for resource demand of buyers, i is the resource consumer,

$provide\_amount$ means the overall resources supply, h is the resource provider.

Consequently, the overall load can be described by formula 3.7.

$$load_t = \frac{\sum_{i=1}^{N} \sum_{j=1}^{K} |\omega_j \, a_{ij}|}{\sum_{h=1}^{N} \sum_{j=1}^{K} |\omega_j \, a_{hj}|} \tag{3.7}$$

ω_j represents the weight of each kind of resources and is determined by system performance.

At the moment t, if $load_t > 1$,then it means the supply is not adequate to the demand and the price can be raised to $p_h^t = p_h \times \left(1 + \left(\frac{1}{1+load_t}\right)\right)$.

If $load_t < 1$,then it means the supply exceeds demand and the price should be reduced to $\mathrm{p_i^t} = \mathrm{p_i} \times \left(1 - \left(\frac{1}{1+\mathrm{load_t}}\right)\right)$.

3.4 The description of SAGA

Genetic algorithm (GA) is still one of the best methods to solve the winner determination problem. GA [17] has a good performance in global search and can determine all the solutions in solution domain at a short time without falling into the local optimum. Besides it can be used in distributed computing conveniently due to its inherent parallelism. But the poor local search ability leads to the high time-consumption and low efficiency in the late stage of evolution .In practical applications, GA may cause problem of premature convergence .The process of GA is as **Table 1** describes:

Table 1. The process of GA

```
Create an initial population randomly
For i from 1 to generation number
    For j from 1 to population size
        Select parents
        Create new_solution with crossover and mutation operators
        If new_solution is infeasible
            Solution =new_solution
        End if
    End for
    Create next population
    If stop condition is met
        Stop the algorithm
    End if
End for
```

Simulated Annealing algorithm (Simulated Annealing, SA) is a stochastic optimization algorithm which is based on the Mente Carloiterative solution strategy. Its starting point is the similarity between solid matter annealing process and general combinatorial optimization problems.SA starts from a certain initial temperature and search the optimal solution in the solution space with the temperature decreasing.

Genetic algorithm converges to probability of "1" to the optimal solution of a problem, in the practical application[18], however, the genetic algorithm tends to be premature and the local optimization ability is poor. Simulated annealing algorithm is a random algorithm, which can avoid falling into local optimal solution of the problem. This paper adopts the combination of genetic algorithm and simulated annealing algorithm (SAGA) to solve the winner determination problem .The detailed process of SAGA is as **Table 2** describes:

Table 2. The process of SAGA

```
Initialize the variables of GA and SA
Create an initial population randomly
For i from 1 to generation number
    For j from 1 to population size
        Select parents
        Create new_solutions with applying crossover and mutation on parents
        $\Delta t$ = fitness(parents) -fitness( new_solutions)
        If $\Delta t < 0$
            New_solutions accept to new generation
        Else
            If exp ($\Delta t / T$) > rand (0~1)
                New_solutions accept to new generation
            Else
                Parents go to new generation
            End if
        End if
    End for
    Decrease T
    If the stop conditions are satisfied stop the algorithm
End for
```

In **Table 2**, the fitness function of offspring is calculated in SAGA. If the fitness of offspring is larger than the fitness of parent, offspring should be put in population, else it can be put in population with probability exp ($\Delta t / T$). And then the fitness function of the next generation can be calculated. Repeat this process until population size and generation number reach terminated condition. Finally optimal solution is obtained.

The SAGA is applied to solve the winner determination problem which is introduced in the section 4.

4. Trust value evaluation mechanism

There exists some malicious users and service providers in the cloud resource managements which lead to the adverse developments in the market [18,19]. Trust is one of the most complex concepts in network communities. It invovles many factors, such as assumptions, expectations, behaviors, risks, and so on. In [20] an innovative trust model was proposed, in which multiple factors were incorporated to reflect the complexity of trust. The properties(weights) of these factors were dynamically assigned by weighted moving averge and orderd weighted averaging combination algorithm. The trustworthiness of cloud services is a critical issue that hinders the development of cloud applications, and thus is an urgently-required research problem. In [21] a trustworthy selection framework for cloud service selection, named TRUSS, was proposed. Aiming at developing an effective trust evaluation middleware for TRUSS, the method proposed an integrated trust evaluation method via combining objective trust assessment and subjective trust assessment. In [22] an automated trust value rating model, based on the expectancy-disconfirmation theory from market science, was defined to overcome feedback subjectivity issues. It put forward global trust value which was unique for each node. The global trust value was obtained by iterative calculation based on history. All the nodes chose the other nodes according to the global trust value.

In order to encourage the healthy developments in cloud resource market, based on the combinatorial double auction model proposed in the previous section, we introduce a trust evaluation mechanism into our model. The model provides a reference for the allocation of resources via mutual evaluation and score update mechanism. All participants' evaluation scores which is called statistical trust value are stored in the model. For resources providers and resources consumers (users), the trust evaluation mechanisms are different as follows:

4.1 The trust evaluation mechanism of providers

Resource provider[23] acquires statistical trust value from the trade history and mainly depends on two factors: direct trust evaluation and indirect trust evaluation[24,25]. In [23] a hybrid model to calculate the trustworthiness of service providers was formulated. Users can choose services with the assurance that the provider will not act malignantly. Cloud services were evaluated and trust value was calculated based on compliance and reputation of providers. Service logs based compliance reflected dynamic trust. In [24] a variety of trust factors and coefficients related to the network application were established to obtain direct and indirect trust values through calculating weightd average of trust factors according to the behaviors of nodes. In [25] the proposed method introduced the third-party trust evaluation model based on existingdirect and indirect (recommended) trust evaluation models as well as the time decay factor. When a user makes a bargain with provider, he will leave a trust score record to the provider. This is called direct trust value. All users' and provides' trust scores make up the direct trust table. Indirect trust evaluation means that users and provides acquire a trust score record via other participants who are in the same system and can be connected with each other. Indirect trust evaluation is based on the direct trust score table. Assume that provider j may have a bargain with user i . Before the bargain,j's statistical trust value based on user i should be provided and this value is based on both direct and indirect trust evaluation. After the combinatorial double auction algorithm, auctioneer assign the user i's tasks to provider j and j will complete the task. When user's tasks is completed, user will evaluate provide by his services. After the evaluation, the direct trust score will be updated and. The direct and indirect trust scores are calculated as the following principles.

For the convenience and intuition of introduction, in this model, providers and users are regarded as nodes and the trust scores between them are regarded as the distance between nodes. Define D_{ij} as the direct trust score between i and j.After a deal, user evaluates the provider and gives a trust score ranging [-1, 1].If the trust score is greater than 0 then the service is regarded as satisfied; If the trust score is smaller than 0 than the service is regarded as dissatisfied; The number of satisfied and unsatisfied transactions between node i and node j is denoted by $Sat(i,j)$ and $UnSat(i,j)$ .The total evaluation score is denoted by $Sum(i,j)$.Consequently, D_{ij} can be calculated by formula 4.1.

$$D_{ij} = \frac{Sum(i,j)}{Sat(i,j)+UnSat(i,j)} \tag{4.1}$$

From formula 4.1 we may know that the value of ranges [-1, 1].

When a transaction is completed, node i evaluates node j's service and gives a score. The value D_{ij} of will be updated according to the formula 4.2.

$$D_{ij}{}' = \frac{D_{ij} \times (Sat(i,j) + UnSat(i,j)) + cuurent\_score}{Sat(i,j) + UnSat(i,j) + 1} \tag{4.2}$$

If $current\_score > 0$, then $Sat(i,j) + 1$, otherwise $UnSat(i,j) + 1$.

4.2 User's statistical trust value

User's statistical trust value is also based on scoring. After user's evaluation on the providers, their given scores will be estimated and divided into fair scoring and unfair scoring. In order to guarantee the validity of the scoring, we introduce score reliability standard in the model. After a deal, user i gives provider j a $score(i,j)$, while the provider has a previous STV_j (statistical trust value).Let $\Delta = |score(i,j) - STV_j|$,if $\Delta \leq 0.75$ then the score is a fair one; otherwise it is unfair.

Let $Fair(i)$ and $UnFair(i)$ to be the number of fair scoring and unfair scoring, then user i's statistical trust value can be described by the following formula 4.3.

$$D_{ij} = \frac{Fair(i) - UnFair(i)}{Fair(i) + UnFair(i)} \tag{4.3}$$

4.3 Trust transmission

Indirect trust score is acquired by trust transmission[24,25,26]. For those users and service provides who had never made a bargain before, the trust scores between them remain unknown. Indirect trust score helps them to measure the other's trust score in the bargain. For example, there exists direct trust score between node i and node j as well as node j and node k, then the indirect trust score between node i and node k can be calculated via the following trust transmission:

If the direct trust score between node i and node j is D_{ij},the direct trust score between node j and node k is D_{jk},the indirect trust score between node i and node j can be calculated as the following formula 4.4.

$$ID_{ik} = D_{ij} \times D_{jk}, \tag{4.4}$$

Besides, there may exist multiple different transmission paths between node i and node j.The topology of nodes is shown in **Fig. 2**, if all the paths are taken into consideration, the complexity of the whole algorithm will be too large. In order to give consideration to both system performance and efficiency, the depth of transmission path is up to 2.

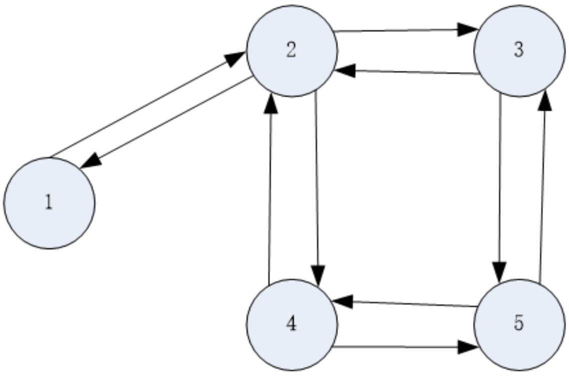

Fig. 2. topology of nodes

From **Fig. 2**, there is no direct trust path between node 1 and node3.Before making a bargain with node 3,node1 has to calculate the indirect trust value between them. Firstly, node1 searches all the paths whose depth is 1 and calculates the indirect trust value correspondingly. The average of all the indirect trust value can be seen as the depth 1's indirect trust value marked as ID_{ij_1}.The calculation process is as formula 4.5.

$$ID_{ij\_1} = \frac{\sum_{n=1}^{N1} D_{ik} \times D_{kj}}{N1} \quad (4.5)$$

$N1$ means the number of indirect nodes whose depth is 1.In figure 4.1 the result of ID_{ij_1}.

Afterwards, search for all the nodes whose depth is 2 and calculate the corresponding indirect trust value. The average of them is regarded as the depth 2's indirect trust value and marked as ID_{ij_2}. The calculation process is denoted by formula 4.6.

$$ID_{ij\_2} = \frac{\sum_{n=1}^{N2} D_{ik} \times D_{kh} \times D_{hj}}{N2} \quad (4.6)$$

N2 means the number of indirect nodes whose depth is 2.

Since different depths result in different trust level, the final indirect trust score is calculated via average as the formula 4.7.

$$ID_{ij} = \delta ID_{ij\_1} + \vartheta ID_{ij\_2} + \cdots, \delta + \vartheta + \cdots = 1, \delta, \vartheta \ldots > 0 \quad (4.7)$$

UTV(unique trust value) means the weighted summation of both direct and indirect trust score between a pair of nodes. Direct trust value plays a more important role for users and its weight is higher. The UTV is calculated as formula 4.8.

$$UTV = \alpha D + \beta ID, \alpha + \beta = 1, \alpha > \beta \geq 0. \quad (4.8)$$

The current node's STV is the average of all the single trust scores as formula 4.9.

$$STV = \frac{\sum_{i=1}^{Node} UTV_i}{Node} \quad (4.9)$$

Node means the number of all the existing users.

4.4 Trust regulatory factors

When acquiring consumers' and provides' trust scores, users have to refer to these scores and convert them into TP or TC. **Table 3** shows the conversion between trust scores and their corresponding regulatory factors.

Table 3. trust value and their corresponding regulatory factors

STV of providers	Trust level of providers	TP\TC
[-1,0)	very unreliable	5
[0,0.25)	unreliable	1.5
[0.25,0.5)	medium reliable	1
[0.5,0.75)	reliable	0.85
[0.75,1]	very reliable	0.7

Define $q_j = \begin{cases} TC(j) \times p_j \\ TP(j) \times p_j \end{cases}$, while $TC(j)$ means the trust value of consumer and $TP(j)$ means the trust value of provider.

After introducing the trust value evaluation into the cloud resource allocation model, the cloud resource allocation problem which is described in the section 3 can be modified by formula 4.10-4.12:

$$max \sum_{j=1}^{N} q_j x_j \tag{4.10}$$

$$s.t. \sum_{i=1}^{N} a_{ij} x_i \leq 0, \forall i \in I \tag{4.11}$$

$$X = [x_1, \cdots x_n], x_i \in \{0,1\}, \forall j \in \{1, \cdots, N\} \tag{4.12}$$

Finally, by calculating the model which consists of formula 4.10-4.12 by running SAGA algorithm, we can obtain the specific resource allocation scheme.

5. Simulation and analysis

5.1 The introduction of CloudSim

On April 8th, 2009, GRIDS Lab and the Gridbus Project at The University of Melbourne, Australia announced the release of the new cloud simulation software, which is called CloudSim.

CloudSim[27] supports research and development in the emerging field of Cloud Computing, and offers the following novel features:1.support for modeling and simulation of large scale Cloud computing infrastructure, including data centers on a single physical computing node; 2.a self-contained platform for modeling data centers, service brokers, scheduling, and allocations policies. Among the unique features of CloudSim, there are: (1) availability of virtualization engine, which aids in creation and management of multiple, independent, and co-hosted virtualized services on a data center node; and (2) flexibility to switch between space-shared and time-shared allocation of processing cores to virtualized services. These compelling features of CloudSim would speed up the development of new algorithms, methods, and protocols in Cloud computing, hence contributing towards quicker evolution of the paradigm.

Apart from CloudSim, there are two other main cloud simulation software GreenCloud[28] and MDCSim[29]. In the terms of simulation time, CloudSim has second performance while GreenCloud has minute performance. In the terms of graphical interface, CloudSim can be added the CloudAnalyst[30] to configure global parameters of cloud applications. However, MDCSim provides no graphical interface. As a result, this paper chooses CloudSim as our cloud simulation software.

5.2 Simulation results and analysis

5.2.1 The simulation of the efficiency of SAGA

To evaluate the stability of SAGA, we compare SAGA with common GA in observing the algorithm convergence. We simulate 400 participants and perform each algorithm 10 times. Before the simulation we define some needed parameters which are listed in **Table 4**.

Table 4. Parameters in SAGA

Parameter	Value
Population number	400
chromosome number	16
crossover probability	0.5
mutation probability	0.05
Number of population genetics	20
Variation of temperature T	T=T*0.9

The simulation results are shown in **Fig. 3** and **Fig 4**.

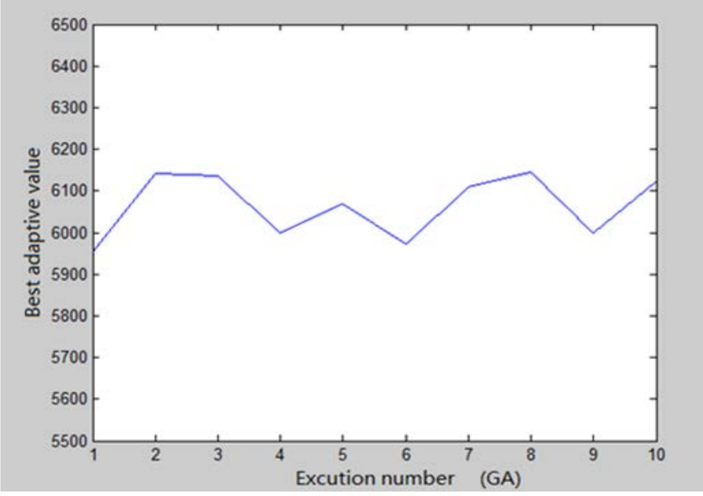

Fig. 3. The best adaptive valve of GA

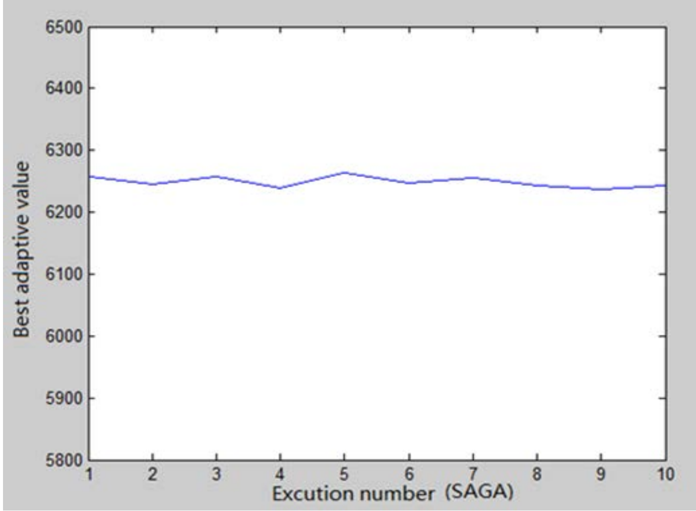

Fig. 4. The best adaptive value of SAGA

The main influencing parameters of Genetic Algorithm are population number, crossover probability and mutation probability. Crossover probability controls the crossover operator which plays a leading role in Genetic Algorithm, and it influences the global search capability of Genetic Algorithm. Mutation probability controls frequency of the mutation operation which is used, and it influences the local search capability of Genetic Algorithm. Population number directly affects the convergence and computation efficiency of Genetic Algorithm. So we change population number, crossover probability and mutation probability to continue to verify the validity of the proposed algorithm. The changed parameters are listed in **Table 5**.

Table 5. Parameters in SAGA

Parameter	Value
Population number	500
chromosome number	16
crossover probability	0.7
mutation probability	0.08
Number of population genetics	20
Variation of temperature T	T=T*0.9

The simulation results are shown in **Fig. 5** and **Fig. 6**.

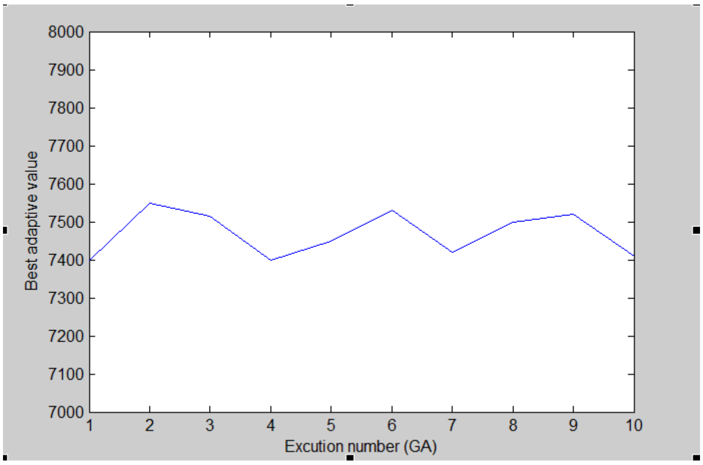

Fig. 5. The best adaptive valve of GA

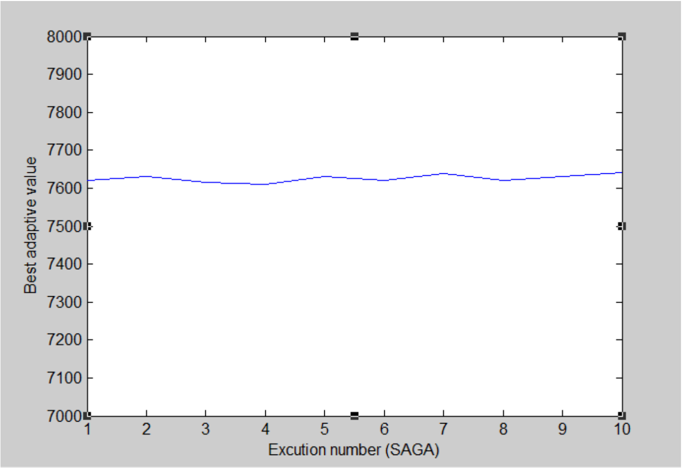

Fig. 6. The best adaptive value of SAGA

The main influencing parameter of Simulated Annealing Algorithm is variation of temperature T. So we change variation of temperature T to continue to verify the validity of the proposed algorithm. The changed parameter is listed in **Table 6**.

Table 6. Parameters in SAGA

Parameter	Value
Population number	500
chromosome number	16
crossover probability	0.7
mutation probability	0.08
Number of population genetics	20
Variation of temperature T	T=T*0.95

The simulation results are shown in **Fig. 7** and **Fig. 8**.

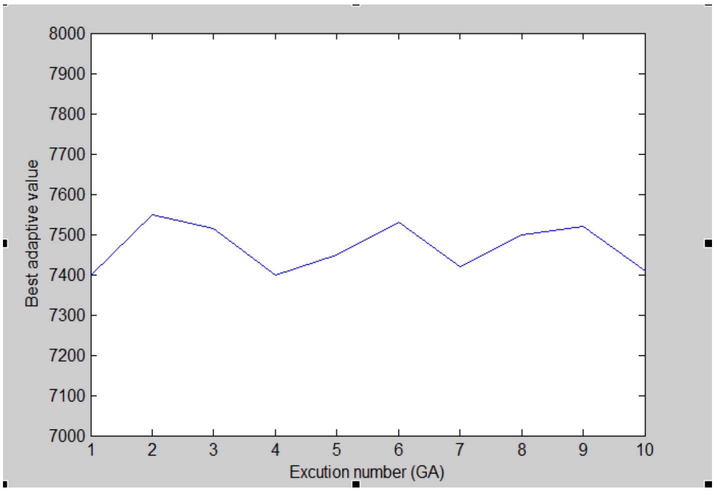

Fig. 7. The best adaptive valve of GA

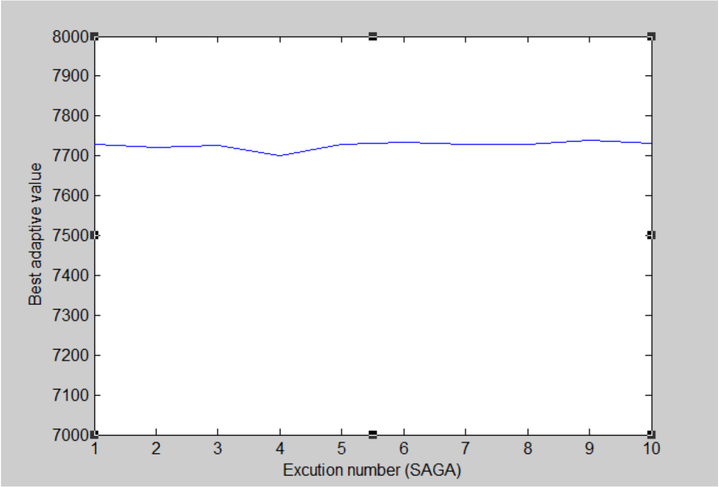

Fig. 8. The best adaptive value of SAGA

From the results we can see that the distinctness of the solutions which are obtained from SAGA are smaller than that of SA, consequently, SAGA has a better stability.

In order to test the computing time and algorithm performance of SAGA, we choose 10 groups of samples and each sample has 100,200...1000 bidding documents respectively. The results are shown in the **Fig. 9** and **Fig. 10**.

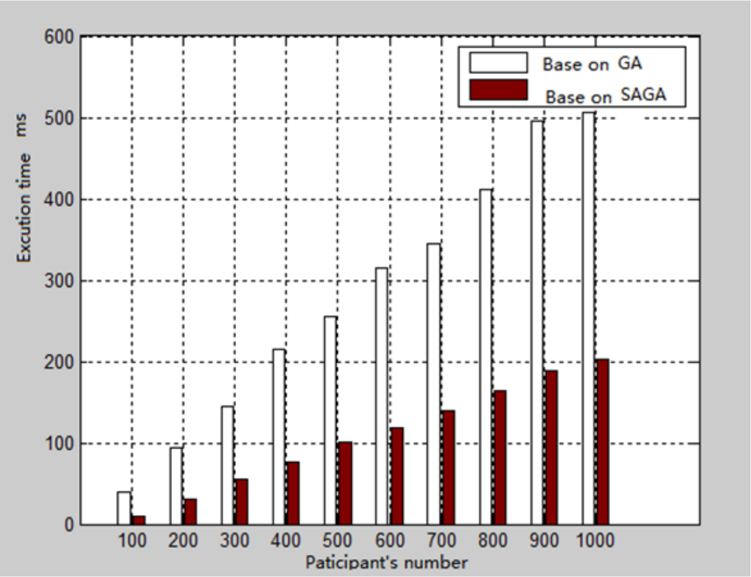

Fig. 9. Execution time comparison of GA and SAGA

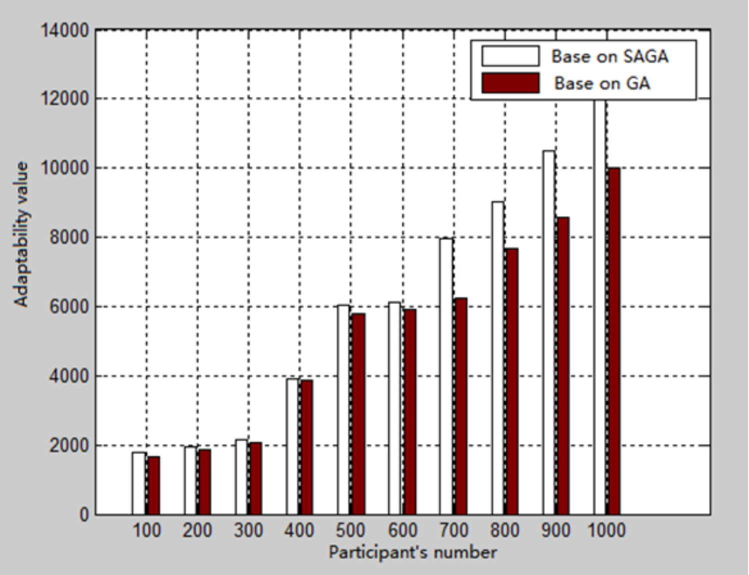

Fig. 10. Adaptability value comparison of GA and SAGA

From the results we can see that SAGA has a better performance in finding optimal solutions, especially when the number of bidders increases.

5.2.2 The simulation on the effectiveness of trust model

Before the test we have to define the parameters which are involved in the algorithm. **Table 7** lists the main parameters and their values.

Table 7. Parameters in trust model

Parameter	Value
δ	0.8
ϑ	0.2
α	0.8
β	0.2

In order to test the effectiveness of our trust model, we simulate 200 nodes, half of them are consumers and half of them are resource provides. The number of transactions between nodes are 1000 times. We set the percentage of both malicious consumers and resource provides at 10%.During the whole process of simulation, the number of each node's successful transaction will be recorded. The specific parameter configurations are listed in the **Table 8**.The result of the simulation are shown in the **Fig. 11** and **Fig. 12**.

Table 8. Specific configurations at 10% level

The percentage of malicious nodes	Providers：10%	Users：10%
The number of malicious nodes	N*10+1（n=0~9）	N*10+8（n=0~9）

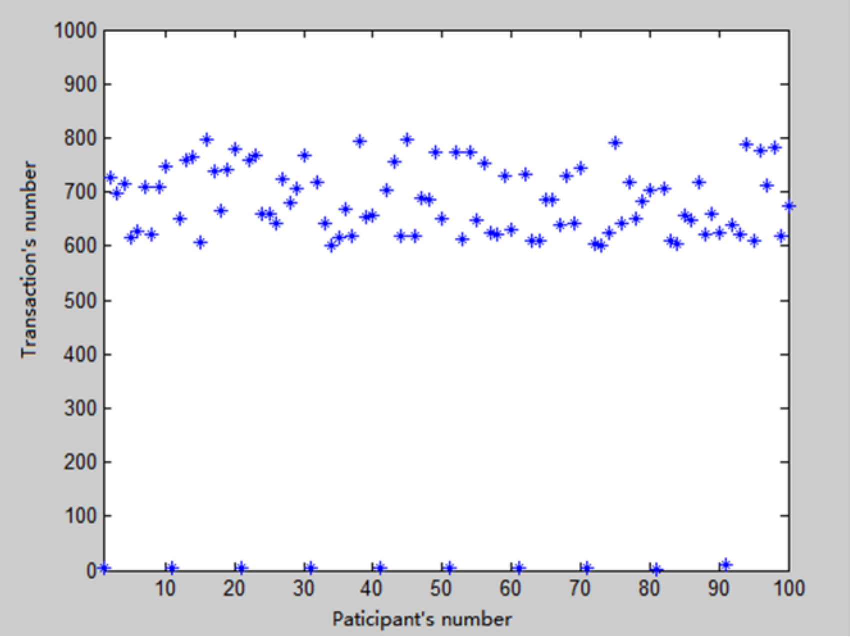

Fig. 11. Transaction number of each node when the percentage of malicious SP is 10%

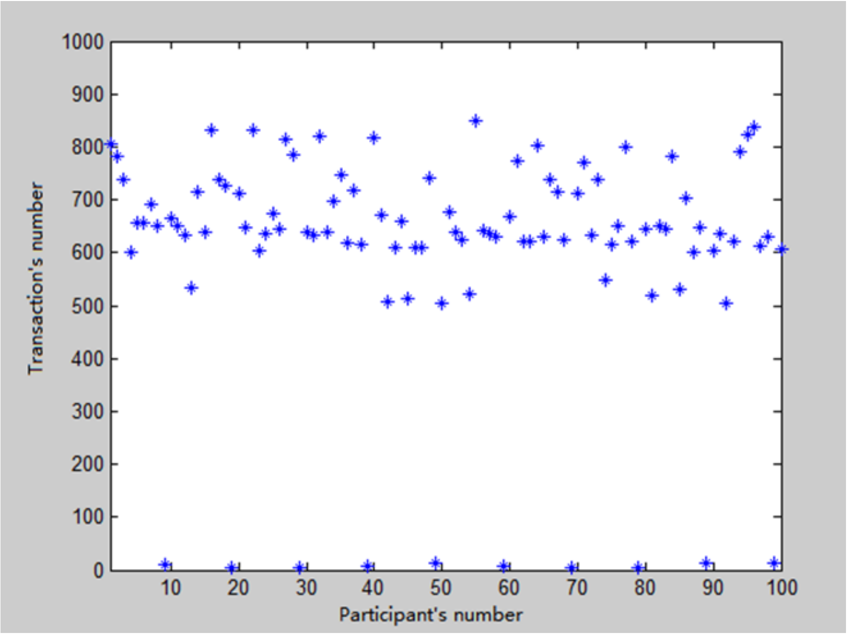

Fig. 12. Transaction number of each node when the percentage of malicious users is 10%

From the results we can see that our model meets the demands of trust evaluation since the transaction amount of both malicious service providers and malicious users is much smaller than that of normal service providers and normal users.

In order to further describe the impact on the transaction amounts which is brought by the malicious nodes and normal nodes, we adjust the number of malicious nodes to50 and the number transaction to 1000 while setting the percentage of malicious to 10%, 20%, 30%, 40%, and 50% respectively. The results are listed in the **Table 9** and **Fig. 13**.

Table 9. Specific configurations and simulation results

The percentage of malicious nodes	The average number of successful transactions			
	Malicious SP	Normal SP	Malicious users	Normal users
10%	6.8	619.9	5.3	620.1
20%	5.4	534.6	2.2	535.4
30%	5.6	492.7	2.8	493.9
40%	5.9	507.3	3.7	508.7
50%	2.6	267.5	2.3	268.1

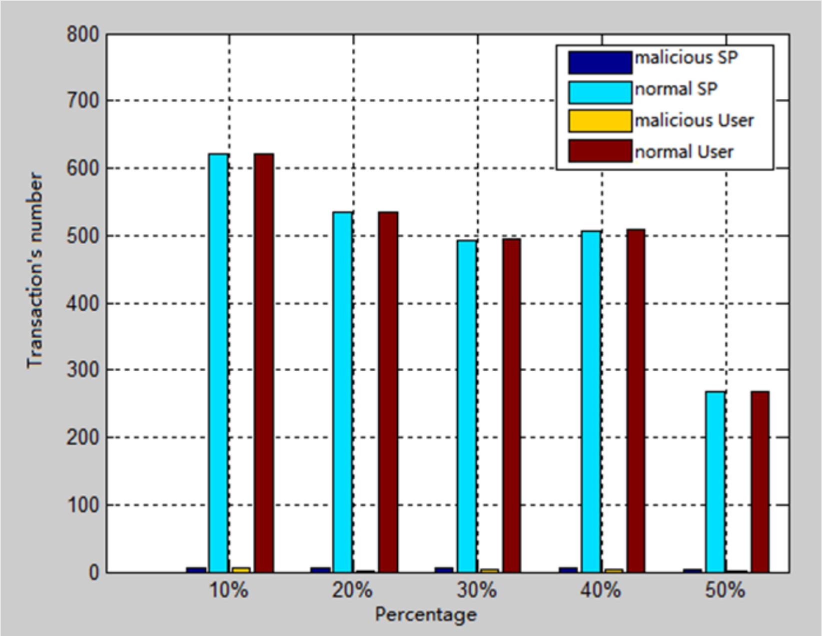

Fig. 13. Transaction's number of normal\malicious users and SP under different percentages

The results of **Fig. 13** shows that the malicious nodes' average successful transaction amount is only about 1% of the normal nodes' amount. Consequently, normal nodes have more chances to participate in the cloud resources allocation and our model and allocation algorithm is effective.

6. Conclusion and prospect

The purpose of cloud computing is to realize the secure resource sharing worldwide via the Internet, consequently, the core of cloud computing technique is resource management and allocation. In this paper, we have completed the following research:

1.We propose a cloud resource architecture based on combinatorial double auction (CRACDA) which consists of user agent layer, middleware layer, and resource management layer and design the detailed interactions between each modules.

2.We combine SA and GA to solve the winner determination problem of resource allocation which is a NP-hard problem in combinatorial double auction. The results of the simulation show that our SAGA has a better performance in the cloud resource allocation.

3.We introduce a trust evaluation model in the auction model which effectively reduces the transaction number of both malicious users and service providers.

However there still exist a lot of problems to be urgently solved. Our future work will focus on:

1.Improving delivering mechanism of trust model. In this paper, we propose the trust delivering mechanism to get the indirect trust score by the mutual trust and the route among nodes. We note that it takes much time to search routes among nodes. A better delivering mechanism should be established.

2.Proposing a pactical algorithm for pricing. In this paper, the resource allocation algorithm is based on the condition that both service providers and users have already set their prices; however, in actual market environments, a variety of factors may influence the prices and it is the key factor to the success of auction. Consequently, to provide a practical and reliable pricing algorithm should be taken into consideration in our future research.

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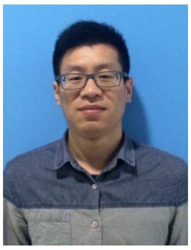

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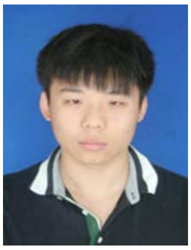

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