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An Optimized Resource Allocation Model for Cloud Computing Using Ant Colony-based Auction Method

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Abstract: Cloud computing is a recent technical advancement in the distributed environment. The cloud offers different types of services to clients with rental policies. The increasing number of smart devices is continuously offloading the task to the cloud for processing. The major issues the Cloud environment faces are resource scheduling and cost management. The cost-based model for resource selection and optimization technique for resource scheduling in cloud computing is developed. The auction model proposed is used to select the resources based on the offers provided by the cloud service provider. The ant colony optimization mechanism is applied to schedule the tasks to the resource based on time and cost constraints. The proposed Ant colony-based Auction method is implemented using cloudsim and compared with Ant colony optimization, genetic algorithm, and min-min approach. The results prove that the proposed method is efficient in terms of completion time, energy consumption, and cost required for task processing.

Keywords: *Cloud Computing, Auction Model, Ant colony method, Resource Optimization, pheromone, Resource scheduling, MakeSpan*.

1. Introduction

Cloud computing offers many computing services through the internet. The three fundamental and popular services provided are infrastructure-as-a-services, software-as-a-services, and platform-as-a-services. Several advancements in technologies have driven computing to offer many other services such as customized services based on the user specific requirements. With strong standards and policies cloud has gained trust among common people. The recent evolution from the cloud is mobile cloud, fog computing, edge computing, and mobile edge computing. Though there are many supporting infrastructures proposed the fundamental resources for the cloud are cloud data centers. The evolved technologies complement the cloud but cannot completely replace the cloud. Hence cloud computing is ever researched field of interest among researchers and academicians.

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In recent years, distributed computing plays a vital role in data computation. Cloud computing is one among them which has the advantage of a rich computation platform and distributed environment [1-3]. Cloud data centers are facing issues in handling a huge number of tasks from smart devices. The workflow is dynamic, to handle the unpredictable load at any point in time, it is significant to apply dynamic load balancing algorithms. The load balancing algorithms maintains the quality of services without overflow or underflow of a task to the virtual machines.

Load balancers applied in the scheduling algorithms play a vital role in assigning tasks to the resources optimally. The parameters considered for the decision making is important to achieve efficiency in task processing.

Cloud computing is supported by several virtual machines with heterogeneous resources. The users have different options in selecting virtual machines with different configurations [4]. The resources in the cloud environment support the dynamic nature where we can enhance or reduce the capacity. Hence the cloud platform is heterogeneous, highly dynamic, and uncontrollable in nature.

The existing methods are not sufficient for resource management in the cloud, it is because they will take control over the resources and requests. However, cloud resources are located in different geographical regions and belong to different domains. Decentralization is one of the solutions to manage cloud resources. To manage user requests, a suitable resource management solution is required. In recent years, the development of the resource management market has increased rapidly. The major advantage of resource management supportable market is to provide the clients and the service providers to take their own decisions in selecting and executing the computing environment [5]. Product market design and public auction design are the two different groups that support resource management [6]. The public auction model deals with the open cost-based mechanism where clients and service providers agree to the constraints. In cloud computing, the CSPs decide the cost of the resources and clients follow the pay-as-you-use policy.

This research work focused on resource scheduling using the ACO algorithm [7] along with microeconomics by considering both time and cost. The ant colony optimization algorithm is inspired by the foraging behavior of the ants in search of food. The proposed model defines the trading cost between the client and CSP. The rest of the research work is organized as follows. Section 2 deals with the recent literature study in the area of scheduling in the cloud. Section 3 deals with the auction-based model for resource identification. Section 4 explains the ACO model. Section 5 deals with the result analysis of the proposed and existing algorithms. Finally, in section 6 the research work is concluded.

The objectives of the proposed work are as follows

1. Propose a metaheuristic approach for task scheduling for a cloud computing environment
2. Consider the quality-of-service requirements of the users
3. Minimize the task processing time, cost, and energy consumption
4. Provider mutual benefits to the service providers and the service consumers based on the auction model proposed
5. Implement the proposed approach using a cloud sim tool and compare it with the existing ant colony, genetic algorithm, and min-min approach.

2. Related Works

This section presents a survey of load-balancing algorithms proposed for cloud computing.

Resource optimization in cloud computing is an ever-ending issue as technology is advancing continuously. Task scheduling and resource segmentation are applied in unification-based resource optimization in cloud computing [1]. This research focuses on multiple objectives for efficient cloud resource distribution. To cope with the dynamic nature of the task metaheuristic algorithms are chosen. A recently introduced one is the cuckoo search metaheuristic algorithm. The proposed approach focuses on uniformly distributing the task among the available virtual machines. The size of the task and the processing power of each virtual machine is considered for task optimization using the cuckoo algorithm [2]. The authors of the research [3] aim to schedule the cloud resources in open-source Open Nebula. It integrated an analytics hierarchy process to choose the best lease from the waiting queue.

Focusing on mobile cloud computing prospective research authors have proposed eDors. The algorithm aims to reduce the cost of task processing by satisfying the task requirements [4].To decrease the pressure on cloud data centers the idle resources from the network are proposed to utilize. The crowdfunding model supports the integration of idle resources for task processing. In addition, a genetic algorithm is applied in scheduling the task [5].In [6] the work proposed focuses on the reliability and availability of cloud resources. A mathematical model is proposed to reduce the time complexity of the task allocation. An extensive survey on resource allocation, task scheduling, different policies applied, and the methodologies focussed are presented [7]

Aiming to reduce the emission of carbon footprints, the authors [8] have proposed a QoS-based scheduling algorithm. The proposed approach is implemented in a cloud sim tool [13] and the results evident the effectiveness of the algorithm. Metaheuristic algorithm Ant colony optimization is applied for task scheduling in the cloud computing environment [10]. The work proposed focuses on decreasing the cost and makespan of task processing and increasing the efficiency of the cloud resources. Particle swarm optimization and the genetic algorithm are applied for task scheduling in cloud computing [11]. The work proposed evaluated the effectiveness based on real-world task data. To minimize the imbalance at the cloud resource allocation, user priority-based QoS is introduced in the work proposed [12]. The users chose the service based on their requirements and the services differ based on their efficiencies and the demand of the payments.

The authors in [15] have focused on task scheduling in a grid environment applying Ant colony optimization. The experiments have been conducted based on the large-scale task workflow, considering real-world parameters. The proposed approach [17] focuses on task scheduling in cloud computing by applying particle swarm optimization. Improved Ant colony optimization-based task scheduling is proposed in [18].

In [14], the trust-based scheduling model mainly deals with model cost. The cost increases with task execution time. The policy is about managing time, cost, and trust. The time and cost can be optimized with the proposed algorithm. But to run large tasks this model is not sufficient. In [15], the authors proposed a seven-heuristic ant colony model for finding an optimal solution to schedule workflow. The ant usually follows the path where there is more pheromone value to find the optimal path. So, the same is followed by the ants in the ACO model. In this model, the disadvantage is completion time.

In [16], for resource scheduling in the cloud, the authors have proposed an improved scheduling algorithm. The algorithm considers objectives as availability of resources and utilization of CPU. Thereby it enhances the scheduling of resources properly with available resources. It has mainly makespan as a limitation in improved algorithms. In [17], to optimize task scheduling the authors proposed a genetic algorithm with Fuzzy logic. To make a decision final task clustering is taken as a major part in resource scheduling. In [18], the main concentration of authors is to develop a heuristic approach for optimal scheduling based on completion time and makespan. However, there is a drawback of less concentration on the consumption of energy in the proposed approach. Though there is much-existing research that focuses on load-balancing algorithms in cloud computing, the cost optimization based on the end users' requirements is not explicitly focused. The existing research integrated many metaheuristic algorithms but it lacks to overcome the issues of long running times without time bonds, and consideration of user quality of service requirements is lacking. Hence the proposed approach has focused on implementing a metaheuristic approach to Ant colony optimization with an auction model to reduce the cost of task processing. In addition, the user's quality of service requirements is also focused.

3. Proposed Auction Method for Resource Cost Estimation

Nomenclature

H_j: Current highest price of the resource *j*

B_j: Base price of the resource *j*

O_{ij}: Offer price of the C_P^i to P_R^j from the list { $O_{1j}, O_{2j}, \ldots O_{lj}$}

MJ: Computing capacity of the resource *j*

M_i: Minimum cost set for the client C_P^i

X_{ij}: the value offered by the P_R^j to C_P^i

th(Xij): Hyperbolic Tangent function

T: Threshold value

The resource cost estimation is processed by using the Auction method [9]. The client C_P has the awareness of the resource cost than the resource provider P_R. In the meantime, P_R concentrates on the profit. Hence the P_R has the additional benefit in the auction method. This research work focused on improvement in the existing auction model [9] towards the benefit of C_P in selecting the resources intelligently. Eq. 1 shows the value offered by the $_R$ to C_P to locate the resource 'i'.$X_{ij} = \left(Q_{ij} + r.m_j\right) \times e^{-\alpha t}$ (1)

$where i = 1,2\ldots l and j = 1,2\ldots k$

Where *Q* represents the past value offered by the P_R to C_P, α value is less than 0and *r* represents the real number, *t* denotes the time duration of the auction, The resource value *X* will be decreased when the auction progress.

3.1 Utility Function

The client's utility function of the resource P_R^j is given as

$$U_{ij} = X_{ij} - H_j - M_i \quad (2)$$

Where X_{ij} represents the resource value offered by the P_R^j to C_P^i, *Hj represents* the current highest price of the resource *j*, and *represents* the minimum cost of the resource *j* set for the client C_P^i. In the auction process, when the highest price and base price of the resource j is equal then the client C_P^i quotes its first offer. If the value offered by the *CPi is* less than or equal to 0 then C_P^i closes its auction process. Eq. 3 shows the highest bid of the client C_P^i to the resource *j*.$O_{ij} = H_j + th(X_{ij})$ (3)

$$th(X_{ij}) = \frac{e^{X_{ij}} - e^{-X_{ij}}}{e^{X_{ij}} + e^{-X_{ij}}}$$
(4)

In Eq. 4, it is clear that the resource value of X_{ij} impacts the value of the O_{ij}.

Case 1: Consider that $X_{ij} = \max_{1 \le i \le n}\{X_{ij}\}$, then X_{ij} is distributed equally in [0, X_{ij}], and

$$pr(X_{2j} = X) = \frac{1}{X_{ij}} \quad (5)$$

$$pr(X_{1j} \le X) = \frac{X}{X_{ij}} \quad (6)$$

Hence, the probability pr (X_{ij})=X, and the next highest value of P_R^j to C_P^i is given as (7)

Eq. 8 shows the estimation of the X which is derived from Eq.7$Est(X) = \frac{l-1}{l} X_{1j}$
(8)

Case 2: Consider that the client C_P^i doesn't know the auction price of each resource in P_R^j and also not known the sequence of resource values (X_{1j}, X_{2j} …X_{nj}), then the client offer to the resource is given as

$$\overline{O_{1j}} = \frac{l-1}{l} X_{1j} + w \quad (9)$$

Where w represents the offer adjustment variable which lies less than 0.

Hence, X_{ij} is selected from (X_{1j}, X_{2j}, …X_{nj}) which is the highest value, The client *CPi's* reasonable offer o the P_R^j is given as $\overline{O_{ij}} = \frac{l-1}{l} X_{ij} + w$
(10) (11)

From Eq. 11, if a>T then P_R^j withdraws from the auction.

Eq. 12 shows the utility function X_{ij} for C_P^i to P_R^j.

$$X_{ij} = O_{ij} - B_j \quad (12)$$

From Eq. 12, if $X_{ij}>0$, then the P_R^j continues the auction process with C_P^i, otherwise withdraws from the auction.

Algorithm 1 shows the auction process mechanism in the cloud Environment.

Algorithm 1: Proposed Auction method

Input: C_P^i -> client

P_R^j->cloud service provider

ct-> counter

Output: Reasonable resource price

Begin

P_R^j -> {m_j ,B_j};

Set ct -> 0

Compute Eq.1 for obtaining the value of X_{ij}

Compute utility function U_{ij} from Eq. 2

If $U_{ij} \leq 0$ then

C_P^i withdraws the auction with P_R^j

Else

Compute the offer O_{ij} of the C_P^i from Eq.3

End if

Compute the value of w for C_P^i which is trading with P_R^j

Cloud service provider (CSP) maintains the value of w

C_P^i-> w

Compute the O_{ij} from Eq.10

if a>T then

P_R^j withdraw from the auction with C_P^i

Else

P_R^j continuous auction with C_P^i

End if

Compute X_{ij} from Eq. 12

if X_{ij}> 0 then

P_R^j continuous auction with C_P^i

Else

P_R^j withdraw from the auction with C_P^i

End if

h=h+1, CSP bargains the highest offer H_j

if h>H then

C_P^i ->H_j wins the auction

H_j is the final highest price

Else

continue from step 2

End if

After resource selection, continue to Algorithm 2 for resource allocation

End

4. Resource Allocation Process with ACO Algorithm

Ant colony optimization algorithm is one of the bio-inspired approaches which is used for solving optimization problems. The ACO algorithm finds the solution to the resource allocation with the help of a search process. In the first level, the ants select the different paths to search for food. After finding the food, the ants calculate the strength of the pheromone at a particular path. Finally, the path with the highest deposit of pheromones is selected as the suitable to search for the food.

The proposed algorithm aims to minimize the execution time and cost. The objective function is defined in Eq.13. $f = min(t) + min(ct)$
(13)

The time constraint is given in Eq. 14 and Eq. 15.

$he \sum_{i=1}^{u} t_i - \mu \leq 0$
(14) $t_i = \frac{\alpha_i}{m_j} i = 1,2..k$
(15)

Where to present ts the task completion time of the resource μ represents the time limit to complete the task. n as alpha $\alpha_i = \vartheta_i - \frac{\sum_{i=1}^{u} \vartheta_i - \beta}{\sum_{i=1}^{u} \sqrt{y_i H_i \vartheta_i}} \sqrt{y_i H_i \vartheta_i}$
(16)

Where ϑ_i represents the average computation rate of te $_R^j$, H_i is the trading offer, y_i represents the conversion unit for P_R^j, and β represents the total number of tasks allocated to the resource. $|\sum_{i=1}^{u} \alpha_i H_i - \sum_{i=1}^{u} ct_i| \leq T, T > 0$
(17)

$$ct_i = \alpha_i \times H_i \quad (18)$$

Algorithm 2 shows the ACO algorithm for resource allocation in cloud computing.

Algorithm 2: ACO algorithm

Input :S->{S_1, S_2…S_n}: set of tasks

R->{R_1,R_2…R_n}: set of resources

Output: Resource Allocation

Begin

Initialize the ants to search for the best resource in R

For each and do

For each S_i do

Compute the possible combination with R

End for

Compute the fitness function of the pair using Eq. 13

If R_i satisfies the QoS parameters then

Allocate R_i to S_i

Update the phe nom ne usi ng Eq. 19 $ph(S_i, R_j) = (1 - v) \times ph(S_i, R_j) + \Delta ph(S_i, R_j)$ (19)

Where Ph(S_i, R_j) represents the pheromone of the (S_i, R_j), evaporation factor is represented w ith v, $\Delta ph(S_i, R_j)$ is the pheromone incremental value.

End If

End For

until it reaches the maximum iterations

End

5. Result Analysis

Cloudsim 3.0.3 is used to simulate the proposed ACO auction model [14]. Tables 1 and 2 show resources and task characteristics. The tasks are independent in nature and the resources are heterogeneous in the cloud.

Table 1. Task parameters

Parameter	**Value**
Size of the File	1026 MB
Number of Tasks	200
Length of the Tasks	2000MIPs
Output Size	50 MB

Table 2. Virtual machine Parameters

Parameter	**Value**
Storage	30GB
RAM	2056 MB
Computing Capacity of the CPU	1860 MIPs
Bandwidth	200 Mbps

In the simulation environment, we considered 20 virtual machines to test the proposed model. The proposed model is tested with average waiting time, energy consumption, completion time, and cost. Fig. 1 explains the task waiting time with different queue lengths L= {20,30, 40}. It is observed there is an increase in the average waiting time for tasks if the queue length increases.

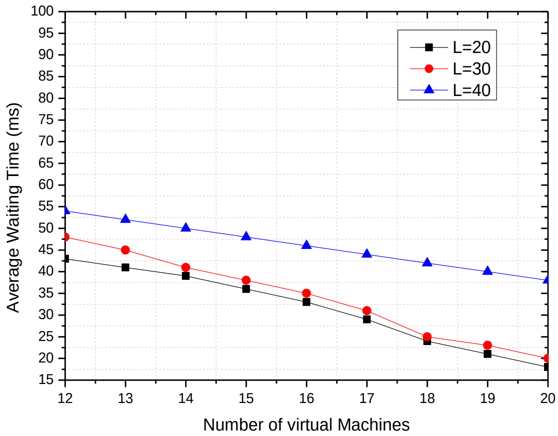

Fig.1. Average Waiting time Vs Number of Virtual machines

The energy consumption in the proposed model is given in Fig. 2. The observed energy consumption in the proposed model is increased when more virtual machines are assigned. The Tasks arrival rate is taken as S={90, 60, 30} and it is noted that energy consumption is reduced when the task arrival rate increases.

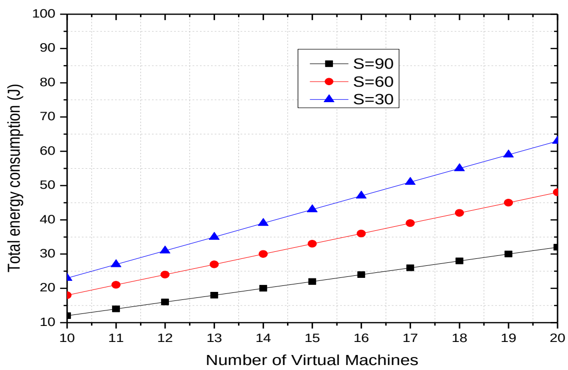

Fig 2. Total Energy Consumption Vs Number of Virtual Machines

The Proposed method is tested with the overall completion time and here we considered three existing algorithms such as Ant colony optimization algorithm [10], Genetic Algorithm [11], Min-Min algorithm [12]. Figure 3 shows the overall completion time of existing and proposed algorithms. It is observed that the proposed model has less completion time compared with other algorithms. It is due to the proposed algorithm following the auction model to hire the resources from the CSPs.

Table 3. Experimental Analysis Concerning Completion Time

Models	**Time (sec)**
ACO Auction	$1.21\ x10^3$
ACO	$1.34x10^3$
GA	$1.42x10^3$
Min-Min	$1.51x10^3$

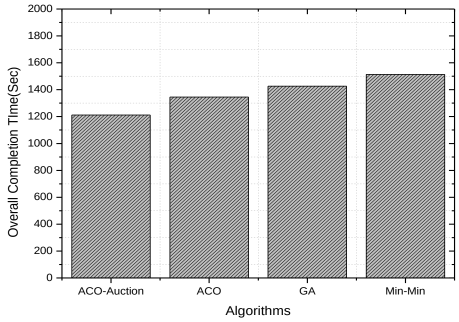

Fig 3. Overall Completion Time of ACO auction model, ACO, GA, and Min-Min algorithms

Fig. 4 explains the scheduling cost of existing and proposed algorithms. The cost of the proposed ACO auction model has less scheduling cost compared with other existing algorithms when 200 tasks are executed in 20 VMs. In the ACO auction model, the client bargains the price at the time of auction with the CSPs. Table 4 shows the scheduling cost of existing and proposed models.

Table 4. Experimental Analysis Concerning Scheduling Cost

Models	**Scheduling Cost ($)**
ACO Auction	124
ACO	175
GA	189
Min-Min	241

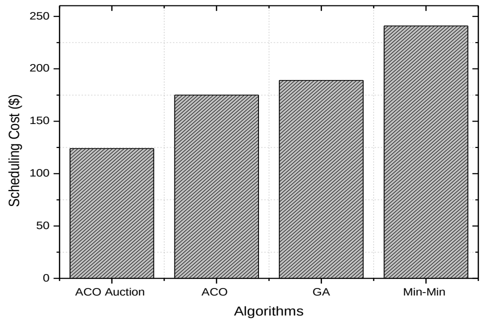

Fig 4. Scheduling cost of the ACO auction model, ACO, GA, and Min-Min algorithms

6. Conclusions

This paper developed the ACO auction model for minimizing the cost of selecting the resources and improving resource allocation. The client had the awareness of the resource cost than the resource provider. In the meantime, the resource provider concentrates on the profit. Hence the resource provider has the additional benefit in the auction method. The auction model helps the clients in selecting the resources intelligently. The ACO model is used to optimize resource allocation in the cloud environment. The performance analysis of the proposed model is tested with the time, cost, and energy consumption of the virtual machines. It is proved that the proposed model is efficient in minimizing the completion time, and cost and reducing energy consumption.

Conflicts of interest

The authors declare no conflicts of interest.

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