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An element search ant colony technique for solving virtual machine placement problem

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Abstract. The data centres in the cloud environment play a key role in providing infrastructure for ubiquitous computing, pervasive computing, mobile computing etc. This computing technique tries to utilize the available resources in order to provide services. Hence maintaining the resource utilization without wastage of power consumption has become a challenging task for the researchers. In this paper we propose the direct guidance ant colony system for effective mapping of virtual machines to the physical machine with maximal resource utilization and minimal power consumption. The proposed algorithm has been compared with the existing ant colony approach which is involved in solving virtual machine placement problem and thus the proposed algorithm proves to provide better result than the existing technique.

1. Introduction

Cloud computing [1-3] is an innovative approach which provides computing services over the internet. The key technique behind cloud computing for designing, developing and delivering the services for the user, makes this approach ground breaking. Due to the attractive advantages like quality of service [ran and lamb], sustainability, accessing speed provided by the cloud environment, it has been widely accepted in short time. Any service provider has the motto to gain high profit simultaneously by reducing the operational cost [1, 2]. To achieve this, the concept of power consumption management has to be taken in to consideration One of the best ways to make cloud computing successful is through virtualization [7, 8]. Virtualization is a technique, which allows sharing a single physical instance of a resources or an application among multiple customers and organizations. It does by assigning a logical name to a physical storage and providing a pointer to that physical resource when demanded. The cloud service provider can ensure the quality of service by obtaining high resource utilization through virtualization.

Virtual machine placement is the process of effective mapping of virtual machines to the physical machines. The optimal mapping is necessary because it plays a major role in improving resource utilization and power maintenance [4-6]. Virtual machine placement is highly used in data center for cloud computing as a key technology to comprehend energy-efficient operation of servers . A data center usually contains thousands of blade servers which are tightly packed to increase the space utilization. The energy consumption problem has already attracted enough attention [9]. Many
efforts have been made to improve the energy efficiency of data center from different aspects including storage power management and network power management [10-14]. Numerous VM placement schemes are designed and proposed for VM placement in the cloud computing environment aimed to improve various factors affecting the data centers, the VMs and their executions.

The next section states the related work which contains different approaches to solve virtual machine placement problem using different optimization algorithms. The third section contains the proposed work, general framework, algorithm explaining the working setup of the proposed system. The fourth section shows the result analysis and performance metrics which is then followed by conclusion and future scope.

2. Related Work

Dong et al. (2014) describe an Ant Colony Optimization based VM placement problem by considering multi-objective problem involved in each of the physical machines. However it is aimed to provide efficient network balancing thereby optimizing the total network traffic. The main focus is to achieve the modification in the availed traffic layout between the individual virtual machine. This modification is implemented by highly minimizing the whole of the traffic using the virtual machine placement in the data center and mapping the virtual machine with large traffic on the similar physical machine. The author also explains the concept of Maximum Link Utilization (MLU), through which network traffic is mapped evenly resulting in the avoidance of congestion. Moreover, for improving performance, they combine the ant colony optimization with 2-opt local search algorithm, because for large data calculation, ant colony optimization has a long way-finding, slow convergence and high time complexity.

Fei ma et al (2012) proposed a multi-objective ant colony optimization algorithm for reducing the SLA violation, resource wastage and power wastage in servers. In this proposed algorithm, for assigning any virtual machine to the physical machine each ant is made to perform solution construction. Once the solution is constructed, the evaluation process is performed, in which the pheromone level is increased only when the constructed solution appears in the list of best solutions, If the constructed solution doesn’t appear in the best solution Otherwise, the pheromone level is made to get evaporated. At last the pheromone updation rule is done. By doing so, the best solution for virtual machine placement will be found.

Gao et al. (2013) present an ant colony system algorithm for analysing and finding solutions for virtual machine placement problem. This is obtained with the set of non-dominated solutions that has been developed for increasing resource utilization and reducing power consumption. The goal underlying this technique is that, complete utilization of the capacities of any servers will result in higher performance degradation. The efficiency is calculated and is compared with multi-objective genetic algorithm, two single-objective algorithms, a bin packing algorithm and a max–min ant system algorithm.

Wang et al. (2013) described the model of Virtual machine placement considering energy consumption of the data centers. The author proposed the method of optimizing energy consumption which is achieved by using PSO algorithm. The technique of redefining parameters provides an energy-aware local fitness first strategy. This method is highly efficient in updating the particle position thereby applying a two-dimensional particle encoding method which will improve the performance of PSO. This technique provides virtual machine replacement for energy consumption.

Zhen et al. (2015) proposed an algorithm for reducing the complexity in consolidated virtual machine placement. This algorithm proves to be novel and is based on biogeography method. This technique considers the consolidated placement problem as a complex system and tries to minimize
both the resource wastage and the power usage. Moreover, thecpu and bandwidth are the important
c constraints considered for resource wastage and power consumption. This technique has been
compared with the existing technique and finds to provide better performance

The problem underlying in multiple virtual machines which is to be mapped for the single
request provided by the host is solved by Gupta et al. (2013). In this approach SLA requirements are
considered as the main constraint for improving resource utilization. In order to achieve this, the High
performance computing-aware scheduling algorithm has been designed for the VM placement which
achieves better resource utilization.

Eagle algorithm has been proposed by Li et al (2011) To address the problem of the online
VM placement in Li et al(2013). This algorithm is to reducing the total number of physical machines
which are busy. In order to achieve this multi-dimension space partition model has been proposed.
Whenever a new virtual machine arrives to get mapped with the physical machines, the resource
utilization of each physical machine has to be calculated. Then the feasible physical machine will be
selected to avoid unnecessary resource wastage. It is efficient in decreasing resource over the long run,
and reducing the number of the PMs.

3. Proposed Methodology

The direct guidance ant colony system for virtual machine placement problem is aimed to provide
effective mapping of virtual machines to the physical machines without wastage of resource and
power consumption. The problem is formulated based on multi-dimensional space allocating
algorithm and bin-packing algorithm. The proposed work contains two dimensional constraints
namely the cpu utilization and memory. The effective allocation is done based on selecting the physical
machine effectively. The physical machine is selected by analysing the utilized and idle capacity in the
physical machine. We use the direct guidance ant colony system for the effective selection of physical
machine. The resource wastage and power consumption model plays a major role for pheromone
initialization and updation. We also introduce the hash-set which contains the list of physical machines
based on their capacity. The hash-set has to be updated after every local-pheromone and global
pheromone updation. Thus the necessity of the ant to search the entire datacentre for selecting the
physical machine will be reduced by the usage of hash-set. This will in turn increase the computational
speed

3.1 Resource wastage model

(Quingua Zhen et al 2012) formulated the resource utilization function based on the resource wastage
model the resource utilization function has been developed to minimize the resource wastage
efficiently.

\[ W_j = | L_{p_j} - L_{j^m} | + \epsilon / U_{j^p} + U_{j^m} \]  \hspace{2cm} (1)

Where,

- \( W_j \) - resource wastage
- \( L_{p_j} - L_{j^m} \) - normalized CPU and memory
- \( U_{j^p} + U_{j^m} \) - normalized remaining CPU and.
- \( \epsilon \) - Small positive real number 0.0001

3.2 Power consumption model

(F.Xang et al 2011) describes the power consumption modeling. The author clearly states that the
power consumption is linearly proportional to the CPU utilization. For energy conservation servers are
turned off when they are idle. Moreover, when the virtual machines are optimally allocated, the
number of physical machine will highly reduce thus resulting in power consumption hence, their idle 
power is not part of the total energy consumption Based on above investigation, and power 
consumption (j) is introduced to quantify total power consumption by jth server. The formula stated by 
the author has been given below. This describes the power consumption factor and the parameters 
involved in the utilization of power and the possible way of maintaining the power utilization without 
any wastage. One should comprehend the power consuming factor in order to maintain the 
consumption.

\[ P_j (j) = y_j^* \left[ (p_j^{\text{busy}} - p_j^{\text{idle}}) \cdot (U_j \cdot p_j^{\text{idle}}) \right] \]  

(2) 

Where ,

\( (p_j^{\text{busy}} - p_j^{\text{idle}}) \) - Average power values indicating busy and idle power values.

3.3 Working of virtual machine placement using direct guidance ant colony

The ant colony approach is a biologically inspired approach which was developed by Dorigo in 1992. 
Based on the food-seeking behaviour of natural ants, the ant colony optimization came into existence. 
This optimization technique found successful and was utilized in various fields like genetic 
engineering, networking and so on. The description about the working setup of direct guidance ant 
colony system for virtual machine placement problem is given below:

3.3.1 Solution construction: The pheromones trail initialization is based on the chemical substance 
secreted by the ants while they move in search of food. This pheromone paves way for the new set of 
ants to find the path. In this paper, the pheromone trail initialization is calculated based on the result of 
power and resource wastage modeling. The pheromone trails are initialized on each of the physical 
machine by which resource and power utilization on each physical machines are calculated. In order to 
calculate the resource and power consumption modeling the two constraints cpu and memory should 
be considered. The cpu and memory demand of each virtual machines are calculated followed by the 
resource capacity of the physical machine in to which the virtual machines are to be allocated. Once 
they are calculated the physical machine containing the least capacity will get the highest pheromone 
value of 0.3 and the physical machine with higher capacity contains least initial pheromone value. 
Thus the initial trail value is set, as stated by [1], which is formulated as,

\[ \tau_0 = 1 / \left[ n* (P(s_0)) + (W(s_0)) \right] \]  

(3) 

Where 

\[ P(s_0) = \sum_{j=1}^{n} [P_j * P_j^{\text{max}}] \]  

(4) 

Where, 

\( P_j^{\text{max}} \) - Peak power consumption in jth server 
\( n \) - Number of virtual machines.

3.3.2 Local pheromone updation: Once the initial physical machine has been selected by the ant based 
on the availability of the pheromone trail, then the arrived virtual machines are allocated in to that
physical machine. Once the allocation has been done then the local pheromone updation is performed. The local pheromone updation [1-2] is based on the formula (7).

3.3.3 Hash-Set updation: Then after the first iteration, the empty hash set should be updated. The hash-set is the one which contains the list of next physical machines which is to be selected. The hash-set is updated by the second group of ants which is initiated after the first local updation. This second group of ants is involved only in hash-set updation. Immediately after the first local updation, this second group of ants starts updating the hash-set. The hash-set updation is performed based on the below stated formula:

\[ hs(i) = \tau_{i,j} + \rho_n \]  

Where

- \( hs(i) \) - hash set i
- \( \tau_{i,j} \) - pheromone value after current local updation
- \( \rho_n \) - Pheromone decay value during that iteration

Once the hash-set updation is being done, in order to make it efficient the max and min trail limits are set for the physical machines capacity. Thus the physical machine with higher trail intensity is set as \( \tau_{\text{max}} \) and the physical machine with least trail intensity is set as \( \tau_{\text{min}} \). The physical machines with intermediate capacities are sorted between \( \tau_{\text{max}} \) and \( \tau_{\text{min}} \). This causes the hash-set to be filled with feasible set of physical machine, which is to be selected in which order.

3.3.4 Global Pheromone Updation: Thus if all the ants have completed the tour, global pheromone updation will be performed. After global pheromone updation, the global threshold value for each physical machine is set, in order to make the physical machine efficient for next iteration.

3.4 Algorithm

Step 1: Initialize the number of ants.
Step 2: Create the empty hash list set
Step 3: Initialize the trail intensity \( \tau_{0} \) using (1).
Step 4: Select the Virtual machine which has to be mapped in the host based on the pseudo-random proportional rule:

\[ \rho_{ij} = \frac{[\alpha * \tau_{ij} + (1-\alpha) \eta_{ij}]}{\sum_{i=1}^{n} (\alpha * \tau_{ij} + (1-\alpha) \eta_{ij})} \]  

(6)

Step 5: Perform local updation rule between the virtual machine \( i \) and host \( j \)

\[ \tau_{ij} = (1-\rho_{1}) \tau_{ij} (t-1) + \rho_{1} * \tau_{0} \]  

(7)

Where,

- \( \tau_{0} \) = initial pheromone factor
- \( \rho_{1} \) = local pheromone evaporating factor whose value lies between 0.1-0.7.

Step 6: Initialize the second group of ants.
Step 7: Update the hash-set using the formula (5).
Step 8: Set max and min trail limit within the hash-set.
Step 9: Repeat this procedure until no virtual machines are available to be allocated to the server.
Step 10: For each set solution perform global pheromone updation

\[
\tau_{ij}(t) = (1-\rho_g) \tau_{ij}(t-1) + (\rho_g \times \lambda) / (P(s) + W(s))
\]

(8)

Where,
\[
\lambda = \lceil NI / t + 1 \rceil
\]

(9)

NI = Number of iteration

Step 11: End for
Until maximum number of iterations are reached.

4. Work flow

Figure 1. Work flow of direct guidance vmpp

5. Experimental Setup

The direct guidance ant colony system for virtual machine placement problem has been implemented using cloudsim. The datacentre has been created which contains the set of physical machine, virtual
machine and the constraints associated with it. The constraints considered are cpu utilization and memory.

The main objective is to optimally allocate the virtual machine into the physical machine without the loss of energy and power. To achieve this direct guidance ant colony system has been proposed, in which the physical machine selection and the pheromone upation plays a major role for optimal mapping. Here the number of physical machines is set 45 and the virtual machines are modified from the range of 60-150. The threshold value of cpu utilization and memory utilization has been fixed to 0.6. As the virtual machines are varied, the number of physical machines taken for optimal mapping is calculated and is compared with the basic ant colony system and the results are tabulated. The computational time for allocating the virtual machines to the physical machines are analyze and compared with the basic ant colony algorithm for virtual machine placement problem and the resulted are tabulated.

6. Result Analysis

The direct guidance ant colony system for virtual machine placement problem has been implemented using cloudsim. The datacentre setup has been made which containing the set of physical machines that are busy and idle. The capacity of each physical machine based on cpu utilization and memory has been analysed. The set virtual machines with various memory and cpu demand that are to be mapped within the physical machines are selected using the above algorithm. Once any virtual machine is mapped, the local updation will be made at the physical machine and this process continues till the entire ant completes their process. Threshold value for cpu utilization and memory will be updated automatically, after every local updation. This will ensure that the virtual machine with higher demand of cpu utilization and memory than the physical machine not to be selected. Then the global updation with global pheromone decay factor is made to perform and the process repeats. This approach is tested with the basic ant colony system for virtual machine placement problem and this found to provide better result.

The graph has been plotted in order to indicate the effective virtual machine allocation in to the physical machine. This is calculated based on the above stated algorithm, in which the pheromone trail initialization, selection of physical machines, threshold value setup, pheromone updation and evaporation are explained clearly for getting the optimal mapping of virtual machine in to the physical machine.

![Figure 2. Mapping of virtual machines](image-url)
After any iteration, the hash list containing the list of next physical machine to be selected is searched. The physical machines are selected based on their capacity which will be updation after single iteration. By doing so, the ant need not search for the best physical machine for which the virtual machine has to be placed, instead the physical machine based on their capacity are placed with max and min values could be selected easily.

![Figure 3. Computational time of vmpp](image)

7. Conclusion

The main motive of direct guidance ant colony system for virtual machine is to attain the optimal solution with high computational speed thereby efficiently allocating the virtual machine to the host effectively which in turn will reduce the total number of host in the system and consumes energy. The direct guidance ant colony system involves the way of initializing the pheromone trail which avoids the random exploration of all the nodes, and the candidate list are updated effectively by segregating nodes based on their trail intrensity and hence the ants can easily select the feasible node for their next traversal. Thus the occurrence of non-feasible nodes could be highly avoided. Graphs are plotted in order to compare performance of the existing algorithm and the proposed algorithm, in which the proposed algorithm provides higher efficiency. This algorithm is implemented in an offline instance of Virtual Machine placement problem and the future scope is to enhance the direct guidance ant colony algorithm to implement it in the online instance of VM placement problems.

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