A Strategy for Optimal Placement of Virtual Machines in IAAS Clouds

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***Abstract*— Cloud computing provides virtualized computing resources that allow cloud consumers to access the resources as pay per use. Such resources must be optimally chosen, in order to process the user request and thereby maximize user satisfaction in the distributed system. Constraint Satisfaction Problem is a prominent technique to optimally choose the resource for placing the virtual machine in large scale distributed system. In this paper, CSP based VM placement strategy is proposed to place the virtual machine in cloud resources and to monitor the resources based on the cpu usage. The CSP always choose a resource which satisfies the constraints as specified by user. VM Manager is integrated with CSP, which optimally places the virtual machine in the cloud resource. Once the virtual machines are placed in the physical machine, the status of the resources is monitored continuously. The virtual machines will be migrated from one physical machine to another, if the cpu usage goes minimal. The proposed work designs a VM Manager along with 2 components called VM Monitor and Resource provisioner in order to minimize the number of physical machines used. CSP based VM placement has been implemented in Java using Eclipse IDE. The proposed technique is compared with First Fit to compare user satisfaction, completion time and number of physical machines. The implementation result shows that the proposed work is accurate when compare to existing technique.**

***Index Terms*— Cloud computing, Constraint Satisfaction Problem, VM Manager, VM Monitor, Resource Provisioner.**

I. Introduction

Recently Cloud computing has emerged as marvelous technology, that delivers on demand computing resources required by cloud consumers over internet using the slogan pay per use. The three major services offered by cloud computing includes: Software as a service, Infrastructure as a service, and Platform as a service. Cloud computing involves lot of serious research issues includes resource management, resource scheduling, reliability, security and virtualization etc.

The two major parties involve in cloud computing are cloud providers and cloud consumers. Cloud Providers are those who provide services as requested by Cloud consumers. The objective of the Cloud providers is to make as much profit as possible. The Cloud Consumers, whose applications are run in the resources of the Cloud Providers, always want their applications to complete within time as well as with stipulated cost.

In this paper, the most prominent research issue called virtualization has been discussed. Cloud Computing provides a platform for consumers to run their applications in more efficient and effective way. Virtualization techniques are used in cloud computing in order to utilize hardware resources as much as possible. Virtual machines are like real system which also contains operating system, that are created usually in physical machine. The virtualization technique increases resource utilization. Though virtualization improves utilization of resources, each VM share underlying physical machine. Through the concept called virtualization, the cloud consumers can utilize computing resources, as pay per use, rather than owning it. Virtualization allows many virtual machines to run in single physical machine.

The placement of virtual machine into physical machine fall into two categories. One is static virtual machine placement and another one is Dynamic virtual machine placement. Figure: 1 represents the types of virtual machine placement.

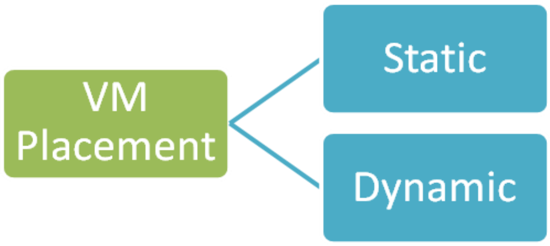

Figure 1: Virtual Machine Placement

In the Static Virtual Machine Placement, the virtual machine will be placed in the physical machine, which satisfies capacity constraints. Figure:2 represents Static Virtual Machine Placement. In case of Dynamic Virtual machine Placement, the Virtual machine will be placed in the physical machine, but when the load of the system increases, the virtual machine will be migrated to another physical machine. Dynamic Virtual Machine Placement is represented in Figure:3

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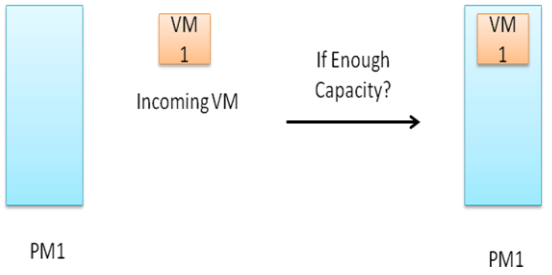

Figure 2: Static Virtual Machine Placement

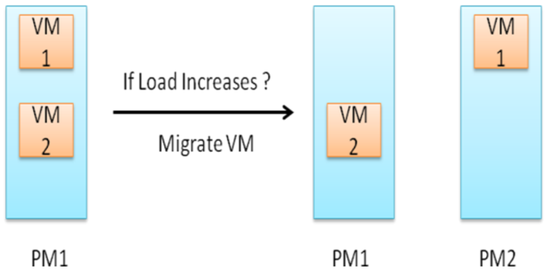

Figure 3: Dynamic Virtual Machine Placement

The main contribution of this paper includes

- Design of Optimal VM Manager
- Best Physical Machines are chosen for each virtual Machine
- Design of Constraint Satisfaction problem based VM placement technique, which considers the completion time
- Comparison of proposed CSP based Placement Technique with First Fit Algorithm.

The rest of this paper is organized as follows: Section II details the related work on Virtual machine Placement. Section III gives the diagrammatic representation of proposed system architecture and detailed explanation of all the modules in the architecture. Section IV gives the implementation details of various algorithms. Section V gives the experimental set up used to implement the proposed work and comparison of results. Section VI concludes the work and gives the future scope.

II. Related Work

Michael TIghe et.al [1] proposed a distributed approach to dynamic virtual machine placement. First Fit heuristic algorithm is used to achieve dynamic and distributed adaptation. This kind of distributed approach eliminates the single point failure. The proposed approach is implemented using DCSim simulation tool. Yongqiang Gao et.al [2] proposed a multi-objective ant colony system algorithm for virtual machine placement. The objective is to minimize total resource wastage and power consumption. The proposed algorithm is tested with various algorithm such as genetic algorithm and bin packing. Kangkang Li et.al [3] proposed migration based VM placement to minimize the job completion time. Offline and online scenarios of Virtual machine placement had considered. The proposed heuristic migration based approach is compared with First Fit and Best Fit. The algorithm places the virtual machine into physical machine which satisfies the capacity. Jiaxin Li et.al [4] proposed multi-tenant VM allocation with the objective to minimize the sum of VM's diameter across tenants. Layered Progressive Multiple Knapsack algorithm had been proposed to properly allocate Virtual machine of multiple tenants. Jipang Gao et.al [5] proposed multi objective particle swarm optimization based virtual machine placement with the objective to minimize number of virtual machine migrations. The parameters considered are CPU, memory and storage. Zamanifar et.al [6] proposed a novel virtual machine placement algorithm to optimize the placement of virtual machine as well as to minimize the data transfer rates between the virtual machines. Minimizing data transfer rate can be achieved through minimizing the delay. Delay depends on size of the file, and location of virtual machines and transfer of data between the virtual machines. Sato et.al [7] proposed a novel dynamic virtual machine placement with the objective to minimize live migrations. Migration of the virtual machines can be minimized by effectively predicting the resource usage. This is implemented using Auto Regressive Model. Yongqiang wu et.al [8] proposed simulated annealing based mechanism to optimally place the virtual machines across servers. The objective is to minimize the power consumption of the servers in the data centers. Shuo Fang et.al [9] proposed a novel virtual machine placement algorithm to minimize the power consumption. OpenFlow protocol had been used to minimize the power as well as to minimize the delay. The proposed method aggregates the virtual machines into group as well it always keeps the virtual machines performing same task in near location.

III. Proposed System Architecture

The proposed architecture is shown in the figure: 4.The components of the proposed architecture include: i) Request Handler ii) VM Manager iii) VM Monitor iv) Resource Provisioner.

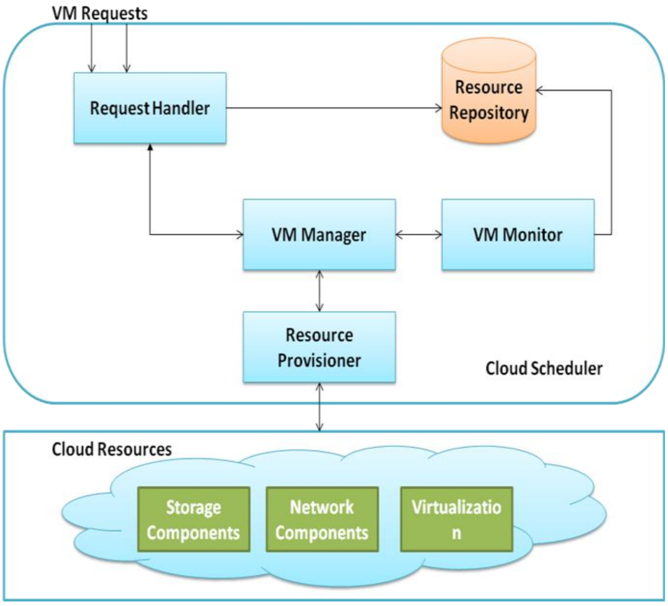

Figure 4: Proposed System Architecture

Request Handler: All the virtual machines submitted by the consumers are handled by the Request handler. The Queuing model adopted for handling the requests is $(M/M/1):(\infty/FCFS)$.

VM Manager: The goal of VM Manager is to allocate appropriate physical machine for the virtual machine. The

VM Manager includes the components VM Monitor and Resource Provisioner. The VM Manager actively manages the mapping of virtual machines to physical machines. The aim of VM Manager is to choose optimal physical machine for each virtual machine. The VM manager is designed using Constraint Satisfaction Problem (CSP).

VM Monitor: Once the virtual machine is placed in the physical machine, VM Monitor keeps on monitoring the virtual machine in terms of its CPU usage. If the CPU usage of the Physical machine drops below threshold,, then the monitor intends to migrate the virtual machine to some other physical machine.

Resource Provisioner: The objective of resource provisioner is to choose optimal physical machine for virtual machine satisfying the demand constraints as well as choosing a resource with minimal completion time of the virtual machine.

IV. IMPLEMENTATION

The problem of placing Virtual machine in the Physical machine is solved using Constraint Satisfaction Problem. The Problem formulation is given as: Let the number of Virtual machines is represented as $|v|$ and the virtual machines are represented as $v \leftarrow \{v_1, v_2, ...v_n\}$. Let the physical machines is represented as $|p|$ and the physical machines are represented as $p \leftarrow \{p_1, p_2, ..p_m\}$. A physical machine p_i has to be optimally chosen for placing the virtual machine v_j. The objective is to minimize the number of physical machines used to place the virtual machines. Also, virtual machine v_j will be placed in the physical machine p_i, if the physical machine is having minimum completion time for v_j.

$$Min \sum_{j=1}^{|v|} \sum_{i=1}^{|p|} X_{ij} \tag{1}$$

Subject to the constraints

$$Min \sum_{j,i} X_{ij} CompTime_{ij} \tag{2}$$

$$\sum_{i=1}^{|p|} X_{ij} \le 1 \tag{3}$$

$$X_{ij} \leftarrow \begin{cases} 0; \text{ if } v_j \text{ is not placed on } p_i \\ 1; \text{ if } v_j \text{ is placed on } p_i \end{cases} \tag{4}$$

$$(Req)_{v_j}^d \le (Capacity)_{p_i}^d \tag{5}$$

While placing the virtual machine in the physical machine, the status of the physical machine has to be monitored periodically. A physical machine may be either of two states

- Over loaded – When the CPU usage of the physical machine exceeds Max threshold value, and then the physical machine is termed to be overloaded. So the virtual machines placed in the physical machine has to be migrated to some other physical machine
- Under loaded – When the CPU usage of the physical machine is below Min threshold value, and then the physical machine is under loaded. So new incoming Virtual machines can be placed into it

The List of symbols used throughout this paper is given in the table: 1.

Symbols	Description
$v \leftarrow \{v_1, v_2, ...v_n\}$	List of Virtual Machines
$p \leftarrow \{p_1, p_2, ..p_m\}$	List of Physical Machines
$\|v\|$	Total Number of Virtual Machines
p_i	i^{th} Physical Machine
v_j	j^{th} Virtual Machine
$\|p\|$	Total Number of Physical Machines
X_{ij}	Boolean variable take either 0 or 1. It will be 1,if j^{th} Virtual Machine run on i^{th} Physical Machine. Else it will be 0.
$CompTime_{ij}$	Completion Time of j^{th} Virtual Machine run on i^{th} Physical Machine
$(Req)_{v_j}^d$	Requirement of j^{th} Virtual Machine across each dimension 'd'
$(Capacity)_{p_i}^d$	Capacity of i^{th} Physical Machine across each dimension 'd'
OP	A set consists of Virtual Machines Mapped with Physical Machines
$(BPM)_{v_j}$	A set consists of Best Physical Machines for j^{th} Virtual Machine
$(cpuUsage)_{p_i}$	CPU usage of i^{th} Physical Machine
$(VM)_{p_i}$	A set of Virtual machines running on the i^{th} Physical Machine
$\|S_{vm}\|$	Total Number of Virtual Machines Successfully placed

Table 1: List of Symbols

The algorithm called CSP-VMPlacement had been proposed to optimally place the virtual machine in the physical machine. The Proposed work functions in two ways: Initially, the algorithm selects the optimal physical machine for placing the virtual machine. Then, periodically it checks status of the physical machine, if the status of the physical machine is found to be overloaded, then the proposed CSP-VMPlacement automatically migrates the virtual machine in the overloaded Physical machine to new physical machine. The CSP-VMPlacement is shown below:

Algorithm 1: $CSP-VMPlacement(\ )$

Input: $p \leftarrow \{p_1, p_2, ..p_m\}, v \leftarrow \{v_1, v_2, ...v_n\}$

Output: $OP \leftarrow \left\{ (v_j, p_i)_{\forall i,j} \right\}$

For $(j = 1; j \le |v|; j++)$

Call $BestPMSelector(\ )$

Call $Placement(\ )$

Call $Migrate(\ )$

End For

The $BestPMSelector()$ is given in Algorithm: 2. A physical machine is considered to be the best for placing virtual machine, if the demand of the virtual machine is satisfied by the physical machine across all dimension d . The dimension represents RAM, Hard disk, bandwidth etc.

Algorithm 2: $BestPMSelector()$

Input: $p \leftarrow \{p_1, p_2, .. p_m\}$

Output: $(BPM)_{v_j}$

For $(i = 1; i < |p|; i++)$

If $\left((Req)_{v_j}^{d} \leq (Capacity)_{p_i}^{d}\right)$ then

$(BPM)_{v_j} \leftarrow (BPM)_{v_j} \cup \{p_i\}$

End If

The $Placement()$ is represented in Algorithm: 3. A physical machine is chosen for placing the virtual machine if the physical machine has minimum completion time for that virtual machine. Once the virtual machine v_j is placed on the physical machine p_i, then the decision variable X_{ij} will be set to 1.

Algorithm 3: $Placement()$

Input: $(BPM)_{v_j}$

Output: OP

For $\forall p_i \in (BPM)_{v_j}$

$\min\_CT \leftarrow FIRST\left((BPM)_{v_j}\right)$

If $(CompTime_{ij} < \min\_CT)$ then

$\min\_CT = CompTime_{ij}$

$PM \leftarrow p_i$

End If

End For

Place virtual machine v_j in physical machine p_i

$(VM)_{p_i} \leftarrow (VM)_{p_i} \cup \{v_j\}$

$X_{ij} \leftarrow 1$

$OP \leftarrow OP \cup \{(v_j, p_i)\}$

The $Migrate()$ is given in Algorithm: 4. After placing a virtual machine v_j in the physical machine p_i, the physical machine has to be periodically monitored in terms of its cpu usage. If the cpu usage exceeds the maximum threshold value, then the physical machine is considered to be overloaded. Then, migrate the virtual machine placed in physical machine.

Algorithm 4: $Migrate()$

Input: $p \leftarrow \{p_1, p_2, .. p_m\}, v \leftarrow \{v_1, v_2, ... v_n\}$

Output: OP

For $\forall\ PhysicalMachine\ p_i$

For $\forall v_j \in (VM)_{p_i}$

If $(X_{ij} == 1)$ then

If $\left((cpuUsage)_{p_i} > MaxThreshold\right)$ then

$(VM)_{p_i} \leftarrow (VM)_{p_i} - \{v_j\}$

Call $BestPMSelector()$

Call $Placement()$

End If

End If

End For

End For

V. EXPERIMENTAL SETUP

The simulation is carried out by generating the virtual machine request and physical machines. The proposed $CSP-VMPlacement()$ is compared with first fit. The Proposed algorithm is compared in terms of completion time, the number of physical machines utilized and user satisfaction. The proposed algorithm outperforms than First Fit.

A. Comparison of Completion Time

The First Fit algorithm always places the virtual machine in the physical machine which has enough room for that virtual machine, as well as First fit algorithm does not consider the completion time of the virtual machine. Thus completion time of the virtual machine increases in First fit when compared to CSP. Figure: 5 shows that proposed algorithm outperforms than the First Fit.

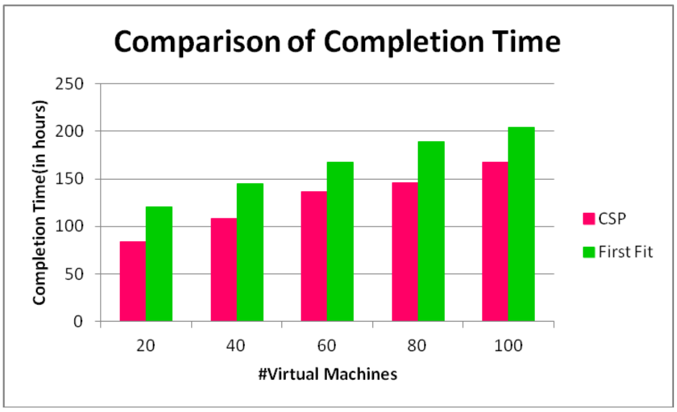

Figure 5: Comparison of Completion Time

B. Comparison of Number of Physical Machines

The Simulation is carried out for comparing the number of virtual machines utilized by the proposed CSP and first fit. From the graph shown in figure: 6 the proposed CSP uses minimum number of physical machines. The reason behind using minimum number of physical machines in CSP, is that proposed technique, always choose a physical machine which is having minimal completion time. In case of First fit, the algorithm always allocates a physical machine which is having more space for that virtual machine. Thus, a physical machine with more space is always chosen, which leads to invoke more number of physical machine.

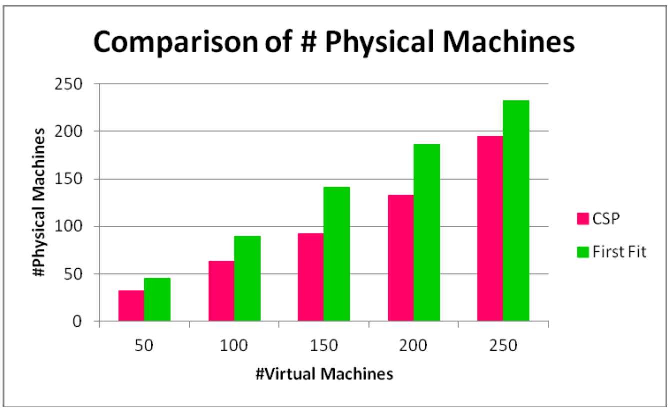

Figure 6: Comparison of #Physical Machines

C. Comparison of user Satisfaction

The simulation is carried out to analyze user satisfaction. User satisfaction is calculated based on number of virtual machines that are successfully completed within deadline to the total number of virtual machines submitted by user.

$$UserSatisfaction \leftarrow \frac{|S_{vm}|}{|v|} \quad (6)$$

The proposed CSP technique achieves maximum user satisfaction than the First Fit algorithm which is shown in Figure: 7.

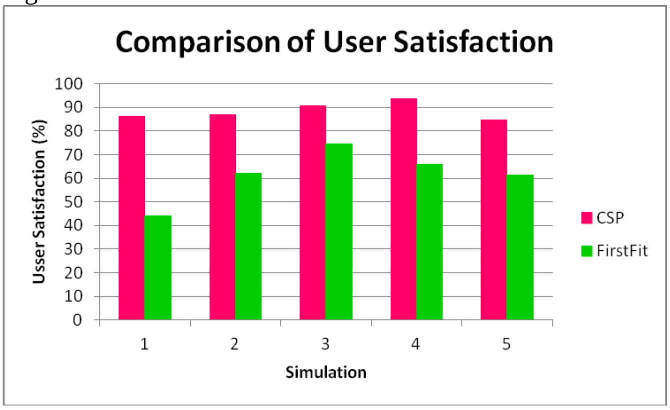

Figure 7: Comparison of User Satisfaction

VI. CONCLUSION & FUTURE WORK

In this paper, we have proposed a novel mechanism to effectively place the virtual machines across various physical machines. Constraint Satisfaction based Virtual Machine Placement had been proposed to minimize the number of physical machines used. The proposed approach also minimizes the completion time of the applications running in the virtual machine by properly placing the virtual machine in physical machine. Constraint Satisfaction Based VM placement algorithm is integrated with VM Manager. The proposed CSP based VM Manager improves efficiency of placing the virtual machines. We have also illustrated that the proposed research work effectively places the virtual machines across various physical machines. The proposed mechanism minimizes the number of physical machines used as well the completion time of the applications. The proposed approach maximizes the User Satisfaction. The future work will be placement of virtual machines based on forecasting the demand of the virtual machines in advance.

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BIOGRAPHY

Ms. Rajalakshmi Shenbaga Moorthy received her B.Tech under the stream of Information Technology from Mookambigai College of Engineering in 2010. She completed her Masters in Engineering (M.E) in Computer Science from Madras Institute of Technology, Anna University in 2013. She is Gold Medalist in her B.Tech and M.E programme. She is currently working as an Assistant Professor in St. Joseph's Institute of Technology, Chennai. Her research area includes Cloud Computing, System Software, Analysis of Algorithms and data mining. She has published four International conference papers, which is indexed in IEEE explorer and Elsevier publications. She has also published one International Journal.

