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Optimize Virtual Machine Placement in Banker Algorithm for Energy Efficient Cloud Computing

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***Abstract**: Energy efficient utilization of data center resources can be carried out by optimization of the resources allocated in virtual machine placement through live migration. This paper proposes a method to optimize virtual machine placement in Banker algorithm for energy efficient cloud computing to tackle the issue of load balancing for hotspot mitigation and proposed method is named as Optimized Virtual Machine Placement in Banker algorithm (OVMPBA). By determining the state of host overload through dynamic thresholds technique and minimization migration policy for VM selection from the overloaded host an attempt is made to efficiently utilize the available computing resources and thus minimize the energy consumption in the cloud environment. The above research work is experimentally simulated on CloudSim Simulator and the experimental result shows that proposed OVMPBA method provides better energy efficiency and lesser number of migrations against existing methods of host overload detection-virtual machine selection and therefore maximizes the cloud energy efficiency.*

***Keywords**:* energy efficiency; virtual machine placement; live virtual machine migration; load balancing; host overload detection; virtual machine selection.

INTRODUCTION

Cloud Computing refers to the means of providing computing power as Infrastructure, Platform and Software applications to end users as a service based on pay as you go pricing model. Prevalent use of cloud computing resulted advancement in the number of hosting data centers which have brought forth many concerns, including the cost of electrical energy, cooling, peak power dissipation and carbon emission. The issue of tackling high energy use can be addressed by removing improficiencies and waste which occurs in the way computing resources get involved to serve application workloads which can be achieved by improving the resource allocation and management algorithms.

Researchers have shown that many of the touted gains in the cloud model are attained from resource multiplexing through virtualization technology reinforced by the concept of virtual machine. Virtual machine associated features such as adaptable resource provisioning and migration have increased efficiency of resource usage and dynamic resource provisioning capabilities as a result of which several challenges cropped up which include balancing load amongst all PMs, determining which VM to place on which PM and managing unexpected escalation in resource demands. So, the focus is on the problem of energy efficient cloud computing through optimized VM placement in data centers, by ensuring that computing resources are efficiently utilized to serve application workloads to minimize energy consumption.

RELATED WORK

Energy efficient utilization of data center resources can be carried out in two steps as explained by Piyush Patel et al., in the year 2012 [1]:

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a) The first is efficient resource allocation through virtual machine placement, and
b) The second is the optimization of the resources allocated in first step through live migration.

Optimization of current allocation of VMs is required when the current host for VM runs out of resources due to overload and is carried out in 2 steps as explained by Piyush Patel et al., in the year 2012 [1]:

a) At the first step VMs that require to be migrated from the overloaded host are chosen and
b) At the second step the selected VMs are placed on the host machine by VM allocation algorithm.

Anwesha Das (2012)[2] in her research describes that all the algorithms which try to efficiently allocate resources on-demand through live migration answers four questions:-

a) determining when a host is considered as overloaded;
b) determining when a host is considered as under-loaded;
c) selection of VMs that should be migrated from an overloaded host; and
d) finding a new placement of the VMs selected for migration from the overloaded and underloaded hosts.

Zhen Xiao et al. in 2013[3] introduced the concept of skewness to measure the unevenness in the multi-dimensional resource utilization of a server where n is the number of resources and ri is the utilization of ith resource and is calculated as:

$$\text{Skewness (p)} = \sqrt{\sum_{i=1}^{n}} (\text{(ri /r)-1)2}$$

By minimizing skewness, authors tried to improve the overall server resource utilization by combining different types of workloads and authors also evolved set of heuristics to prevent system overload effectively to save energy. The algorithm achieves overload avoidance as well as green computing for systems with multi-resource constraints.

In 2011 [4] Richa Sinha et al. proposed a dynamic threshold based approach for CPU utilization evaluation for host at data center. The

CPU utilization of all VMs and upper threshold value is calculated evaluated as:

Uvm = totalRequestedMips / totalMipsforthatVM,

Sum = $\sum$ Uvm , Sqr = $\sqrt{\sum}$Uvm2

Tupper = 1-(((Puu * Sqr) + sum) – ((Pul * Sqr)+sum))

Best Fit Decreasing (BFD) heuristic of bin packing is used for VM placement and dynamic threshold based live migration is performed for VM selection. The consolidation works on dynamic and unpredictable workload avoiding unnecessary power consumption.

Author Girish Metkar et al. in 2013[5] presented a method which uses a lower and upper level threshold to evaluate host overload and under load detection and are calculated as follows:

$$U_{vm} = \text{totalrequestedMips, Sum} = \sum U_{vm}$$

$$\text{Bw} = \sum \text{current bandwidth for VMs for host,}$$

$$\text{Ram} = \sum \text{current Ram for VMs for host}$$

$$\text{temp} = \text{Sum} + (\text{Bw}/\text{Bw(host)}) + (\text{Ram} / \text{Ram(host)})$$

$$T_{upper} = 1 - 0.5 * \text{temp and } T_{lower} = 0.3$$

Minimization migration policy is used for VM selection to minimize the number of migrations as well as the energy consumption. The proposed method performs threshold-based dynamic consolidation of VMs with auto-adjustment of the threshold values.

In 2012[6] authors Anton Beloglavoz et al. defined an architectural framework and concepts for useful resource provisioning and allocation algorithms for energy efficient management of cloud computing environments. Modified best fit decreasing (MBFD) algorithm is used for VM placement along with minimization of migration, highest potential growth and random selection policy of VM selection. Following power model is used by the authors to calculate energy:

$$P(u) = k.\ Pmax + (1\text{-}k).\ Pmax\ .\ U$$

Here Pmax is the maximum power consumed by fully utilized server, k is the fraction of power consumed by the idle server, and U is the CPU utilization. The proposed energy aware allocation heuristics provide data center resources to client applications such that energy efficiency of datacenter is improved, while delivering negotiated Quality of Services.

In [7] authors Ajith Singh N. and M. Hemalatha tried to do hotspot mitigation using banker algorithm for VM placement by checking whether the system is in safe state or unsafe state while allocation to avoid high chances of deadlock while resource allocation. Overload detection techniques of median absolute deviation (MAD), inter quartile range (IQR), local regression (LR), local regression robust (LRR), static threshold (THR) and VM selection algorithms of minimum migration time (MMT), maximum correlation (MC), minimum utilization (MU) and random selection (RS) in combination with specified overload detection techniques to determine when the migration is to be initiated and which virtual machines to migrate.

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VM migration algorithms try to adapt to changing workload conditions by turning the knobs of resource allocations through triggering migrations. Thus, live VM migration has become an indispensable tool for resource provisioning and virtual machine placement in a virtualized environment.

SCOPE TO OPTIMIZE VIRTUAL MACHINE PLACEMENT IN BANKER ALGORITHM

This paper focuses on VM placement using existing Banker algorithm which considers availability of multidimensional resources and ensures a deadlock free resource allocation. Ajith Singh et al., in the year 2013 [7] used various overload detection and VM selection methods along with banker algorithm for VM placement and evaluated the performance of several methods yielding better results in terms of number of migrations, average Service Level Agreement (SLA) violation and energy consumption. However, in [7] no technique is incorporated to detect system overload based on dynamic utilization threshold values to enable system automatically change its behaviour depending on the subjected workload patterns by the applications as used by Richa Sinha et al., in the year 2011 [4]. Moreover Anton Beloglazov et al., in the year 2010[6] and Richa Sinha et al., in the year 2011[4] uses minimization migration policy which selects VM to migrate based on its utilization with respect to its current host utilization and threshold value of the host and ensures least number of virtual machine migrations for VM placement optimization. Hence the author in this paper proposes use of dynamic threshold technique for host overload detection and minimization migration policy of VM selection for optimization of VM placement in Banker algorithm. The proposed combination of methods is expected to provide with better results in terms of energy efficiency, percentage SLA violation and number of migrations.

PROPOSED METHODOLOGY

In the adopted methodology, **O**ptimized **V**irtual **M**achine **P**lacement in **B**anker **A**lgorithm for energy efficient Cloud Computing is named OVMPBA, the technique of **D**ynamic **T**hreshold used for host overload detection is named as DT and **M**inimization **M**igration policy for VM selection is named as MM.

Dynamic Threshold (DT) Technique for Host Overload detection:

Threshold value is used to decide the time when the migration is to be initiated from a host. When the system load exceeds the threshold value, the system is detected as overloaded. Dynamic threshold (t) value for a host is calculated in following steps-
Firstly CPU utilization for all VMs on the host is calculated as:
Uvm = total Requested MIPS / total MIPS for that VM
Then, allocated RAM and Bandwidth for all virtual machines and host is calculated as:
Bw= ∑ current bandwidth for VMs for host
Ram = ∑current Ram for VMs for host
Sum=∑Uvm
Temp= Sum+(Bw/Bw(host)) + (Ram/Ram(host))
t = 1- 0.5*temp
For a host whose utilization value exceeds the threshold value ‘t’ some virtual machine migrations will be performed.

Minimization Migration(MM) Policy for VM Selection:

Once a host is determined as overloaded, some virtual machines requires to be migrated from the current host to lower down the utilization threshold. It is very difficult to decide which VM to migrate because if a large VM is selected, the total migration time will increase and if smallest VM is selected then number of VMs will be migrated. So, the minimization migration policy selects the VM whose size is equal to the difference between the total host utilization and the threshold value.
Following are the steps of Minimization Migration policy which returns the list of VMs that can be migrated:

Input: hostList, vmList
Output: migrationList
1. vmList.sortDecreasingUtilization()
2. for each host in hostList do
3. hUtil ⟵h.util()
4. bestFitUtil ⟵ MAX
5. while hUtil > h.thresh() do
6. for each vm in vmList do
7. if vm.util() > hUtil − h.thresh() then
8. t ⟵ vm.util() − (hUtil − h.thresh())
9. if t < bestFitUtil then
10. bestFitUtil ⟵ t
11. bestFitVm ⟵vm
12. else

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13. if bestFitUtil = MAX then
14. bestFitVm ← vm
15. break
16. hUtil = hUtil − bestFitVm.util()
17. migrationList.add(bestFitVm)
18. vmList.remove(vm)
19. return migrationList

To optimize VM placement in Banker algorithm DT-MM method works together for efficient optimization of the VM placement plan. The method is compared against existing methods Inter Quartile Range (IQR), Local Regression Robust (LRR), Static Threshold (THR) of host overload detection and Maximum Correlation (MC), Minimum Migration Time (MMT) and Minimum Utilization (MU) of VM selection in all possible combinations against the parameters of energy consumption, percentage Service Level Agreement violation and number of migrations which are evaluated as follows in the CloudSim simulator:

% SLA Violation:

Overall SLA violation = (a-b)/a

% SLA violation= 100 * Overall SLA violation

Where a=Total Requested MIPS

b=Total Allocated MIPS

Energy consumption:

Energy consumption = Total Utilization of CPU/ (3600*1000)

Number of VM Migrations:

Number of VM migrations = Total Migration Count

IMPLEMENTATION

CloudSim simulator is used to model and test the cloud environment. PlanetLab workload of CloudSim is used in the simulation. The cloud system in PlanetLab workload is deployed in a data centre comprising of two types of physical machines and four types of virtual machines. The target cloud model is an IaaS system with a cloud data center consisting of total ‘N’ physical machines where N=800. N can be represented by N= $\{pm_1, pm_2 \ldots pm_{800}\}$. A set ‘M’ of virtual machines run on physical machines where M=1024 and M can be represented by M= $\{vm_1, vm_2 \ldots . vm_{1024}\}$. The virtual machines on a physical machine can be restarted, paused and migrated to other physical machines in cloud data center. Different Simulation parameters for the PlanetLab workload simulation are defined in Table I

TABLE I
SIMULATION PARAMETERS AND THEIR VALUES

Parameter	Value
Host types	2
Host MIPS	{1860, 2660}
Host RAM	{4096, 4096}
Host Bw	1000000(1Gbit/sec)
VM types	4
VM MIPS	{2500, 2000, 1000, 500}
VM RAM	{870, 1740, 1740, 613}
VM Bw	100000(1Mbit/sec)

Flow Diagram:

The flow diagram of optimized design of virtual machine placement in Banker algorithm through DT and MM (OVMPBA) is shown in figure 1.

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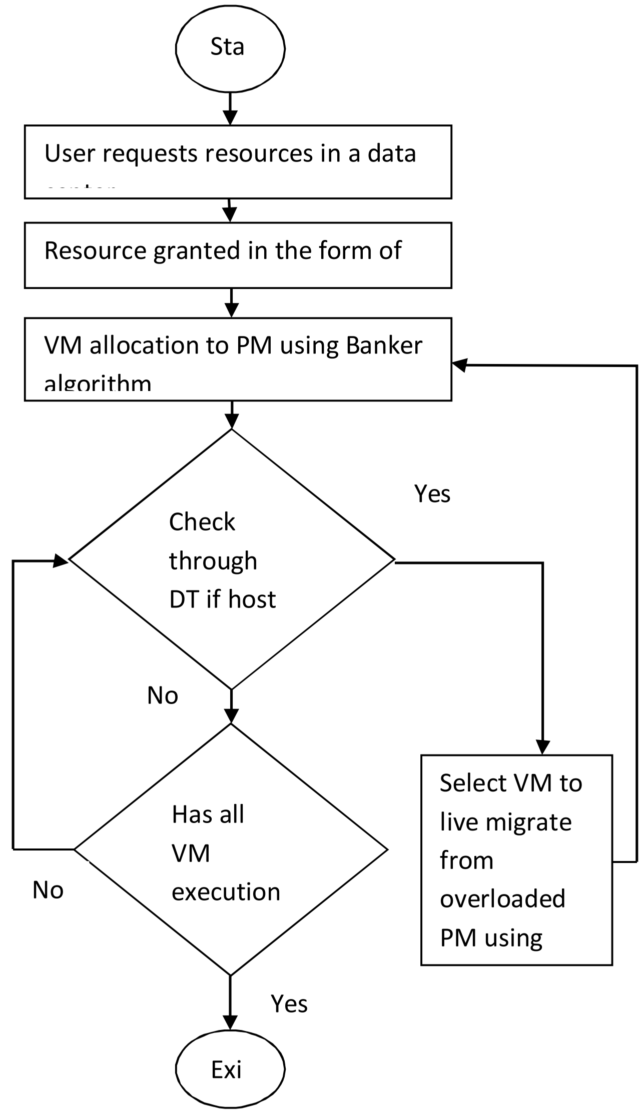

Flow Diagram of OVMPBA

Steps to Optimize Virtual Machine Placement in Banker through DT and MM:
The steps pursued for designing the optimize virtual machine placement in Banker algorithm through DT and MM are as follow:

1) User requests resources in cloud data center.
2) The cloud data center provides the required resources in the form of VMs.
3) The resource scheduling centre in the cloud data center allocates the VMs to a PM in the Banker algorithm.
4) The PM is checked dynamically for overloading through the DT technique as there are chances to develop a hotspot.
5) If a hotspot is detected then some VMs need to be migrated from this overloaded host.The MM policy selects the VM to be migrated and the VM is again received by the resource scheduling center to be reallocated to a different active PM. The previous host is again checked for overloading and if the condition does persists then some more VM are migrated until the PM resource utilization normalizes.
6) Repeat step 4 and 5 until all the active PMs resource utilization optimizes.

For the implementation of above steps firstly Banker algorithm is used for placement. DT technique detects dynamically the host overload as per varying workload demands. The VM selection policy used is MM which optimizes the resource utilization with minimum number of migrations in minimum migration time.

FINDINGS AND RESULTS

After designing the simulation model, configuring the cloud scenario, simulation is executed for both existing and proposed approaches and simulation output are analyzed to obtain the results. Results are obtained for existing overload detection and VM

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selection policy along with the proposed ones and Banker algorithm is used for VM placement. Results are compared by the help of graphs. The performance is evaluated for performance parameters of Energy Consumption in kWh, % Service Level Agreement (SLA) violation, Number of VM migrations. Following tables shows the result of simulating Banker algorithm with various overload detection techniques and VM selection policies:

TABLE II
BANKER WITH OVERLOAD DETECTION BY IQR

OVMPBA	**Energy kWh**	**SLA%**	**Migration**
Overload Detection / VM Selection			
IQR-MC	25.75	0.00033	812
IQR-MMT	24.80	0.00036	830
IQR-MU	26.31	0.00029	780
IQR-MM	25.01	0.00032	785

Table II shows the result of simulating Banker algorithm with IQR overload detection and various VM Selection policies. From this table it can be concluded that Banker with IQR-MMT method consumes the minimum energy of 24.80 kWh, IQR-MU reduces SLA violation to 0.00029% and number of migrations to 780

TABLE III
BANKER WITH OVERLOAD DETECTION BY LRR

OVMPBA	**Energy kWh**	**SLA%**	**Migration**
Overload Detection / VM Selection			
LRR-MC	25.49	0.00034	859
LRR-MMT	24.35	0.00033	865
LRR-MU	24.17	0.00039	820
LRR-MM	25.09	0.00032	830

Table III shows the result of Banker algorithm with LRR overload detection and various VM Selection policies. From this table it can be concluded that Banker with LRR-MU method consumes the minimum energy of 24.17 kWh, LRR-MM reduces SLA violation to 0.00032% and number of migrations to 820.

TABLE IV
BANKER WITH OVERLOAD DETECTION BY THR

OVMPBA	**Energy kWh**	**SLA%**	**Migration**
Overload Detection / VM Selection			
THR-MC	25.62	0.00034	839
THR-MMT	24.49	0.00034	863
THR-MU	26.38	0.00033	840
THR-MM	25.40	0.00032	798

Table IV shows the result of Banker algorithm with IQR overload detection and various VM Selection policies. From this table it can be concluded that Banker with LRR-MU method consumes the minimum energy of 24.49 kWh, THR-MM reduces SLA violation to 0.00032% and number of migrations to 798.

TABLE V
BANKER WITH OVERLOAD DETECTION BY DT

OVMPBA	**Energy kWh**	**SLA%**	**Migration**
Overload Detection / VM Selection			
DT-MC	25.35	0.00033	825

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DT-MMT	24.72	0.00032	818
DT-MU	25.67	0.00030	798
DT-MM	23.01	0.00029	770

Table V shows the result of Banker algorithm with DT overload detection and various VM Selection policies. From this table it can be concluded that Banker with DT-MM method consumes the minimum energy of 23.01 kWh, reduces SLA violation to 0.00029% and number of migrations to 770.

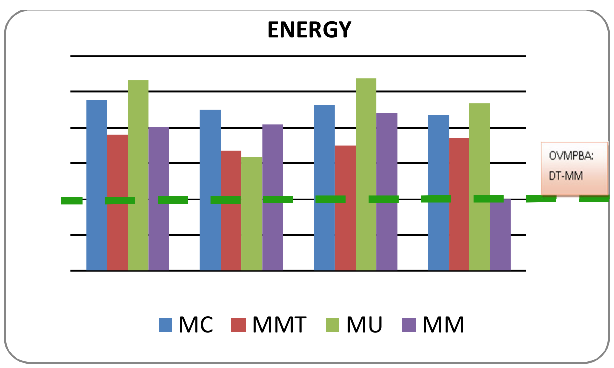
TABLE VI
COMPARISON BETWEEN EXISTING AND OVMPBA RESULTS

Existing Results	LRR-MU 24.15	IQR-MU 0.00029	IQR-MU 779
Proposed Results OVMPBA	DT-MM 23.01	DT-MM & IQR-MU 0.00029	DT-MM 770

Table VI shows the result of existing and proposed approach OVMPBA in terms of energy consumption, percentage SLA violation and number of migrations. In existing methods LRR-MU uses minimum energy of 24.15kWh, IQR-MU gives minimum percentage SLA violation of 0.00029 and 779 number of migrations. OVMPBA results in improved performance with 23.01 kWh energy consumption, and 770 number of migrations. However the percentage SLA violation by OVMPBA is equal to the existing results of method IQR-MU with 0.00029 percentage SLA violation. Ms- Excel is used as the output utility tools for plotting the graphs using the above tables.

Energy Consumption

Graph 1 shows the consumption of energy in the cloud using Banker algorithm with various overload selection and VM selection. Energy (in kWh) is shown along Y axis and overload detection with VM selection policy is shown along X axis.

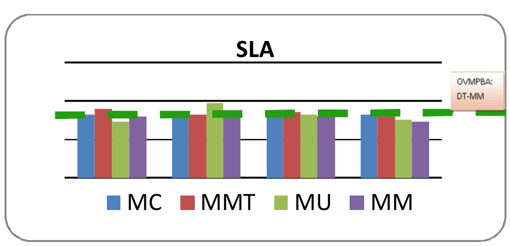


Graph 1. OVMPBA vis-à-vis other methods: Energy consumption of Overload Detection & VM selection.

It can be analyzed from the graph that in the VM placement optimization through DT-MM combination in the cloud environment results in lesser energy consumption as compared to other approaches used for VM placement optimization.

SLA Violation

Graph 2 shows the SLA Violation in the cloud using Banker algorithm with various overload selection and VM selection. SLA violation (in percentage) is shown along Y axis and overload detection with VM selection policy is shown along X axis.



Graph 2: OVMPBA vis-à-vis other methods: SLA violation of Overload Detection & VM selection.

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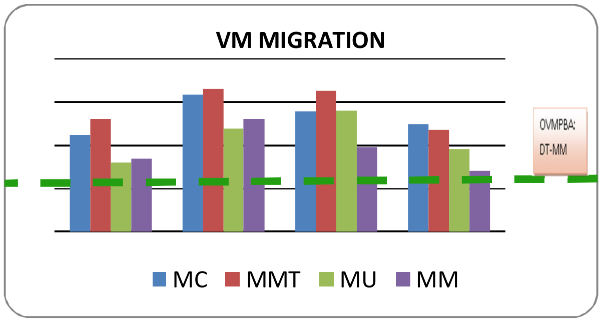
It can be analyzed from the graph that in the VM placement optimization through DT-MM combination in the cloud environment results in percentage SLA violation equal to the existing results of method IQR-MU used for VM placement optimization.

Number of Migrations

Graph 3 shows the number of migration performed in the cloud using Banker algorithm with various overload selection and VM selection. Number of migrations is shown along Y axis and overload detection with VM selection policy is shown along X axis.



Graph 3: OVMPBA vis-à-vis other methods: Number of migrations of Overload Detection & VM detection

It can be analyzed from the graph that in the optimize VM placement in Banker algorithm (OVMPBA) through DT-MM combination in the cloud environment lesser number of VM migrations are performed as compared to other approaches used for VM placement optimization.

CONCLUSION

The author has proposed and investigated a suite of novel techniques for implementing through optimize VM placement in Banker algorithm in IaaS Clouds The proposed method improves the utilization of datacenter resources and reduces energy consumption. Performance of optimize VM placement in Banker algorithm (OVMPBA) through dynamic threshold(DT) and minimization migration(MM) has been compared with other existing overload detection and VM selection algorithms. Through OVMPBA energy consumption was curtailed down to 23.01 kWh, with percentage SLA violation of 0.00029 and 770 numbers of migration. The performance has been compared against these parameters and found to be minimum. Optimize VM placement in Banker algorithm through dynamic threshold and minimization migration algorithm is more energy efficient as compared to exiting methods. The method however provides equal number of SLA violations but minimizes the number of migrations required for VM placement optimization.

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