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A FRAMEWORK AND ALGORITHMS FOR ENERGY EFFICIENT CONTAINER CONSOLIDATION IN CLOUD DATA CENTERS

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***Abstract*:**

Now a day's utilization of power in cloud data centers is very large. Minimization of power consumption in data centers is major challenge. Cloud computing uses a network of remote servers which are hosted on the Internet to process, manage, and store data rather than a local server. Containers in cloud is nothing but an image which is a lightweight, software package which executes independently which hold everything you need to run: code, system libraries, system tools, settings. Using container consolidation, containers are migrated to number of hosts. In Container overbooking, allocate some percentage of workload to any resources. In this scenario hosts having CPU utilization and power consumption less than 70% or more than 80% are considered as underloaded or overloaded. In this paper, focus is on the performance of two algorithms named container overbooking and initial placement of containers and compare the results with scheduling algorithms named FirstFit, MostFull, Random and LeastFull. We will combine the both algorithm and create the algorithm which improves the results with reduced the power consumption in data center and resource utilization.

Keywords: Cloud, energy consumption, cloud data centers, Container consolidation, overbooking

I. INTRODUCTION

Cloud computing is also known as "the cloud", it uses remote servers which are hosted on internet for storage, manage, and processing of data that are delivered on-demand on a pay-for-use basis. Users work remotely using cloud computing. The resources retrieved from the cloud are through web based tool and applications. Cloud computing gives several benefits for business users and clients.

- Self-service provisioning: End users can set up and launch application services in cloud environment and use those resources on demand for any type of workload. This put an end to the conventional requirement for IT administrators to supply and manage compute resources.
- Elasticity: There will be increase in computing needs and also decrease in the needs therefore companies can scale up and down as per demand. It removes the demand of huge expenditure in local infrastructure which may or may not remain active.
- Pay for use: Users use those resources for which they are paid and workloads they use. [4]

The container is nothing but an image which is a lightweight, software package which executes independently which hold everything you need to run: code, system libraries, system tools, settings. The containerized software is available for Linux and Windows based apps and runs the same regardless of the environment. Containers running on the host machine share the kernel of host's operating system; it starts immediately and uses less compute resources and RAM. Images are created from the layers of the file system and share common files. This minimizes disk usage and image uploading is much faster. [1][2]

Consolidation strategy combines the containers which are marked as overloaded. This technique is used for minimization of energy utilization in cloud data centers, containers are migrated on number of hosts which are having smaller support of ContainerCloudSim framework.

This paper focuses on container overbooking and container placement policy algorithms. Container overbooking algorithm first check whether the container is in overbooked or what then if it is overbooking condition then that container needs to migrated to another host. For that it will moved to container migration list. In another algorithm container placement policy uses three algorithms FirstFit, MostFull and Random algorithm.

Based on the results and performance evaluation of above designed algorithms we are trying to design such an algorithm which improves the results of algorithm and reduces the energy consumption in data centers with resource utilization.

Work is carried out in following format; Section 2 elaborates previous work done and technique used for that work by researchers in CloudSim. Section 3 gives brief introduction about ContainerCloudSim, need of simulation and its taxonomy. In section 4 details working about proposed research regarding the Container overbooking, consolidation, container placement policy in Cloud Data Centers by using ContainerCloudSim framework and algorithms and also mathematical model for power consumption in data centers are stated. Section 5 represents discussion about experiment setup and results. Chapter 6 outlines the conclusions of proposed study.

II. RELATEDWORK

In paper [1], Claus Pahl *et al.* give an introduction to Virtualization and need for the Containerization. It has been discussed that to manage and orchestrate applications PaaS cloud service can use containers. Overall the experiment shows about container containerization technologies and how applications can be deployed and run on PaaS platform.

In paper [2], Sareh Fotuhi *et al.* author gives the brief information about ContainerCloudSim. Container is having various advantages over the use of virtual machine. ContainerCloudSim is a framework or tool which facilitates containerized cloud computing environments simulation and modeling support for cloud data center. In this paper author had developed simulation architecture and apply various algorithms on containerized cloud data center and executed it as an extension of CloudSim.

In paper [3], Piraghaj *et al.* carried out CloudSim architecture and various algorithms are applied using CloudSim for minimization of energy utilization in cloud data center with required Quality of Service (QoS). This paper carried out the whole information and related algorithms for simulation of containers, container consolidation techniques. The objective of authors is to address the betterment in the utilization of resource on server and virtual machine.

In paper [5], Piraghaj *et al.* told significant problems that cloud providers face for reducing total energy utilization in cloud data centers by using various algorithms and CloudSim tool or framework. The main focus of author is improving energy efficiency of servers by using the CloudSim framework. This paper introduces about CaaS Service and also impact of container overbooking, container migration etc.

In paper [6], Amir Vahid Dastjerdi *et al.* states classification of various resource management techniques for energy efficiency. Author says that energy utilization in cloud data centers not only affects the overall cost but also it increases the environmental problem as carbon dioxide emission.

In paper [7], Awada *et al.* author proposed that energy consumption becoming key issue for the operation and maintenance of cloud datacenters; cloud computing providers are becoming deeply concerned. In this paper, author presents formulation and solution for Green Cloud Environments to reduce environmental impact and energy consumption by examining static and dynamic portions of cloud components under new models.

In paper [9], M. Khoshkholghi *et. al.* states that cloud data centers can utilize huge amount of energy which contributes to high operational cost and emission of carbon dioxide. To reduce the resource utilization and reduction of energy consumption author proposes a technique dynamic consolidation of VM using migration but VM consolidation may decreases the performance. In this paper different algorithms are proposed for consolidation of VM dynamically.

In paper [10], Buyya Rajkumar *et al.* proposed the CloudSim framework for simulation of data centers in cloud computing environments. CloudSim is used to simplify the application deployment, how resources are allocated and for scheduling algorithms. CloudSim supports one or more virtual machines for modeling and simulation.

In paper [11], Mehiar Dabbagh, Bechir Hamdaoui *et al.* proposed a framework that is integrated energy-aware resource provisioning for energy consumption in cloud data centers. It provides physical machines to cloud data centers for providing services to their clients. Framework contains three main components: power management, clustering and workload prediction.

In paper [12], Wang Long, Lan Yuqing and Xia Qingxin *et al* states that simulation will reduce the effort to configure testing environment and avoids the spending time. In this paper author uses CloudSim framework for simulation provides simulation, power to manage services and to model the cloud infrastructure. It also states VM allocation policy, VM selection policy.

In paper [13], Anton Beloglazov *et al.* says that cloud data centers consume huge amount of electrical power which may results in high operational cost and carbon dioxide emission. The objective of author is minimize energy consumption by migrating the VMs on another host and turn off idle nodes in cloud data center by providing required quality of service to the users.

In paper [14], Kantarci, Burak, H. Mouftah covers the energy efficiency in cloud data center which contains many aspects such as storage and network related power consumption. For energy efficiency in cloud computing author proposes various aspects like processing, storage and power consumption network etc.

In paper [15], Berl, Andreas, *et al.* said that efficiency of energy is essential for future information and communication technologies. In this paper author focuses on efficient energy scheduling in multiprocessor and grid system, minimization of energy in clusters of servers and also impact of energy saving strategies for management of integrated system.

In paper [16], Qouneh, Amer, Ming Liu, and Tao Li., states that energy utilization and performance are two main challenges in cloud computing data centers. To decrease energy consumption and maintain performance author uses two techniques that is, take power from co-located multithreaded virtual machines (VMs) and distribute it to VMs and compensate multi-threaded VMs and re-boost their performance.

In paper [17], Park, KyoungSoo, and Vivek S. Pai., says that CoMon is an evolving, mostly-scalable monitoring system for PlanetLab. In this paper author designs what kinds of data are gathered in PlanetLab.

In paper [18], Kulseitova, Aruzhan, and Ang Tan Fong., proposed that there is need for applying some energy efficiency techniques in cloud data centers. Thus author present a recent research in cloud data centers and gives taxonomy of work.

III. Definition and Model

A. ContainerCloudSim:

ContainerCloudSim is an extension of CloudSim simulator framework. ContainerCloudSim is designed for migration of containers from source host to destination host based on the power consumption in data centers. ContainerCloudSim uses techniques like container overbooking, container placement, scheduling and consolidation of containers. Container as a Service's cloud data center which contains virtual machines, hosts, containers and applications with their workloads. ContainerCloudSim is divided into two parts that is simulated elements and simulated services for implementation. Aim of this technique is to provide energy efficient cloud data centers by migrating container from source host to destination host by applying some algorithms. [2][8]

B. *Need of simulation in Cloud Datacenter*:

Simulation is widely used technology used frequently to examine complex problems, most simulation-based experiments consider simplified modeling of cloud computing and application environments. CloudSim is a library for simulating cloud scenarios. It provides essential classes for describing data centers, compute resources, virtual machines, applications, users, and management strategies for various parts of the system, such as planning and provisioning.

Simulation provides a safe way to test and explore different scenarios. Simulation is used for improvement in performance and energy efficient cloud data center. It is used to know in which ways a part could fail and what loads it can oppose which is helpful for designers and engineers to understand conditions. Simulation is used in many conditions such as, simulation for performance optimization, testing, scientific experiments etc. The main advantage of simulation is it provides users feedback practically while designing real-world systems.

C. *Taxonomy of ContainerCloudSim*

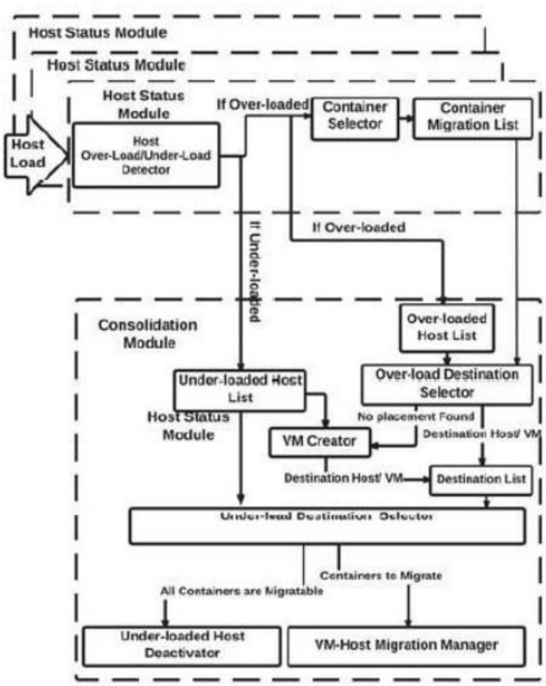

Fig. 3.1 System Architecture and Processes

Figure 3.1 [5] represents the ContainerCloudSim system architecture and processes. The main components of ContainerCloudSim are

- **Host Status Module**

Host Overload/ Underload Detector – It is widely used mechanism. In this module host is established as underloaded or overloaded. If the host is established underloaded then host detector sends host ID and containers ID which are running on that host to consolidation module. And if it established overloaded then detector send request to the Container selector component for activating component.

Container Selector – This component is activated when host in cloud data center is established as over-loaded. This process of selection of containers is goes on unless host status is available in between underloaded and overloaded condition.

Container Migration List (CML) – This component stores the containers information which are selected by Container Selector component and then submit that information to consolidation module.

- **Consolidation Module**

Over-loaded Host list – Task of this component is to store over-loaded host.

Over-loaded Destination Selector – It takes input as overloaded host list, list of containers migration and active host list. Then it migrates the over-loaded host to destination host.

Destination list – This component contains data having container ID with host and VM ID both are received from the above component.

VM Creator – The most important consideration of this component is to create large number of VM's in underloaded host and assigns containers to that VM's. If any container is remaining, then it selects host randomly from the idle host and creates VM on that host.

Underloaded host list – The status of the host that are found to be under-loaded are stored in this component.

Underloaded Destination Selector – The mechanism of this task is to find the best destination host for containers from underloaded hosts by using host selection algorithm. This component sends the containers to the destination which is decided by overloaded destination selector to VM-Host Migration Component along with host ID.

VM-Host Migration Manager – This is used for triggering the migration of saved containers ID together with selected destination.

Under-loaded Host Deactivator – After migrating all the containers this component switches off under-loaded hosts.

IV. EXPERIMENTAL SETUP

To deploy ContainerCloudSim on Eclipse IDE we need to download Simulator which is .zip file of CloudSim-4.0 from GitHub and also download eclipse. Deploy the CloudSim-4.0 by extracting the .zip file and import it in Eclipse.

1. Container overbooking

Overbooking manages the trade-off between maximizing resource utilization and minimizing performance degradation and SLA violation. [2] By allocating some percentage of workload to any resources ContainerCloudSim is capable of container overbooking. In this scenario hosts having CPU

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utilization and power consumption less than 70% or more than 80% are considered as overloaded or underloaded.

Algorithm: Container Overbooking
Input: list of container in server (*SCL*)
Output: selected container
Step 1 begin with input while
Step 2 check for host overloaded
If host status marked as overloaded then go to step 3
Else check host status
either overloaded or underloaded
Step 3 Apply container selection algorithm
to get container from container selection list(*SCL*)
Then add selected container to the list

2. Container consolidation

This technique is used for reducing energy consumption in data centers. Using consolidation technique, containers are migrated to number of hosts which are smaller with support of ContainerCloudSim framework. [5] Migration of containers is necessary because host is either overloaded or under-loaded. Here two algorithms are used "Most Correlated" and "Max Usuage" for container selection. Max usage algorithm select the containers which has most CPU utilization while most correlated algorithm chooses containers CPU workload is most correlated with host. [2]
Finally at last stage three bin packing algorithms for host selection are applied: FirstFit Host Selection, Random Host Selection and Least Full Host Selection.

3. Container placement policy

Here we study different container to VM mapping algorithms to see how ContainerCloudSim is used to carry out systematic inquiry of algorithms on container placement for total power consumption, number of container migrations in data center and resulting SLA violations. FirstFit, MostFull and Random are three different placement policies are evaluated. [5]

- **Mathematical model for power consumption in Cloud Datacenter [5]**

a) Data Center Power Model - Energy efficiency of the data center at time t is calculated as:

$$P_{dc}(t) = \sum_{i=1}^{Ns} pi\,(t) \qquad (1)$$

For each server i, utilization of CPU (Ui,t) is equal to

$$\sum_{j=1}^{Nvm} \sum_{k=1}^{Nc} Uc(k,j,i)\,(t)$$

and the power consumption of the server is estimated using Equation 2.

$$P_i(t) = P_i^{idle} + (P_i^{max} - P_i^{idle}) * U_{i,t} \qquad N_{VM} > 0 \qquad (2)$$

$$0 \qquad N_{VM} = 0 \qquad (3)$$

The consolidation algorithms analyze the energy efficiency based on the data center energy consumption obtained from Equation 1.

b) SLA Metric –

$$SLA = \frac{\sum_{i=1}^{Ns} \sum_{j=1}^{Nvm} \sum_{p=1}^{Nv} CPUr(vmj,i,tp) - CPUa(vmj,i,tp)}{CPUr(vmj,i,tp)} \qquad (4)$$

A Service-Level Agreement is an agreement between two or more parties, where one is the customer and the others are service providers. This can be a legally binding formal or an informal "contract". Service-Level Agreement is a part of cloud computing to ensure maximum availability of services for customer. With violation of SLA, the provider has to pay penalties.

c) Problem Formulation – For minimizing power utilization of data center with M containers, N VM's and K servers, we formulate the problem as follows:

$$min(Pdc(t) = \sum_{i=1}^{Ns} Pi(t) \qquad (5)$$

$$\sum_{j=1}^{Nvm} Uvmj,i(t) < S(i,r)\,,\ \forall i \in [1,Ns], \forall r \in \{CPU\} \qquad (6)$$

$$\sum_{j=1}^{Nvm} vm(j,i,r) < S(i,r)\,,\ \forall i \in [1,Ns],$$
$$\forall i \in [BW, Memory, Disk\,] \qquad (7)$$

$$\sum_{k=1}^{Nc} Uc(t) < vm(j,i,r), \forall i \in [1,Nvm],$$
$$\forall i \in [1,Ns], \forall i \in \{CPU\} \qquad (8)$$

$$\sum_{k=1}^{Nc} c(k,j,i,r) < vm(j,i,r)\,,\ \forall i \in [1,Nvm],$$
$$\forall i \in [1,Ns], \forall i \in \{BW, Memory, Disk\} \qquad (9)$$

Symbols	Description
$P_{dc}(t)$	Power Consumption of the data center at time t
$P_i(t)$	Power Consumption of server i at time t
N_s	Number of servers
P_i^{Idle}	Idle power consumption of server i
P_i^{max}	Maximum power consumption of server i
$U_{i,t}$	CPU utilization percentage of server i at time t
N_{vm}	Number of vms
N_c	Number of containers
$Uc_{(k,j,i)}(t)$	CPU utilization of container k on (VM j, server i) at time t
N_v	Number of SLA Violations
t_p	The time t at which the violation p happened
$Vm_{j\,i}$	VM j on server i
CPU_r (vm j i, t_p)	CPU amount requested by VM j on server i at time t_p
CPU_a (vm j i, t_p)	CPU amount allocated to VM j at time t_p
$S_{(i,r)}$	Server i Capacity for resource r
$U_{vm\,j,i}$ (t)	CPU utilization of VM j on server i at time t
$vm_{(j,i,r)}$	The capacity of resource r of VM j on server i
$C_{(k,j,i,r)}$	The resource r capacity of container k on (VM j, server i)

Table: Symbol table [5]

V. RESULT AND DISCUSSION

We evaluate two algorithms with two methods. We are used ContainerCloudSim to conduct simulation with different parameter such as overbooking factor, container migration rate, execution time, container placement etc.,

A. Container Overbooking

By allocating some percentage of workload to any resources ContainerCloudSim is capable of container overbooking. In this scenario hosts having CPU utilization and power consumption less than 70% or more than 80% are considered as overloaded or underloaded.

B. Container Placement Policy

Here we study different container to VM mapping algorithms to see how ContainerCloudSim is used to carry out systematic inquiry of algorithms on container placement for total power consumption, number of container migrations in data center and resulting SLA violations. FirstFit, MostFull and Random are three different placement policies are evaluated.

- **Scheduling Algorithms**

FirstFit – In the first fit, containers are allocated to virtual machines which are first sufficient from the top of Main Memory. In FirstFit algorithm, available host is opened when it receives the first container. When all the containers in a host are removed from source host, the host is closed. FirstFit algorithm results in less number of migrations and energy consumption.

MostFull – In the most full, containers are allocated to virtual machines which are most correlated with host. MostFull algorithm packs container on most full virtual machine in terms of CPU utilization, which results in higher migration rate.

Random – It typically uses random bits as an input in the hope of achieving good performance in the average case over all possible choices of random bits. In random algorithm, containers are allocated to virtual machines randomly.

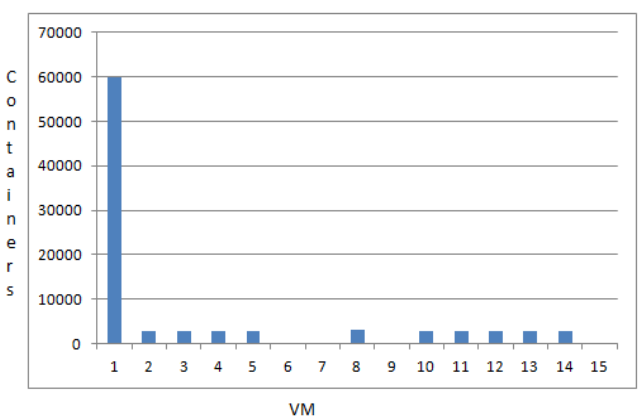

Fig. 5.1 Container Overbooking (FirstFit)

Based on the figure 3 and figure 4 we can say that FirstFit algorithm for container overbooking performs better as compare to MostFull algorithm. The output of the simulation shows that number of successfully allocated containers decreases as percentage of energy consumption increases. The volatility of workload is the key factor that affects the percentage of value. FirstFit algorithm results in less number of migration and energy consumption and thus should be preferred policy to be utilized as the goal of provider is to reduce energy consumption.

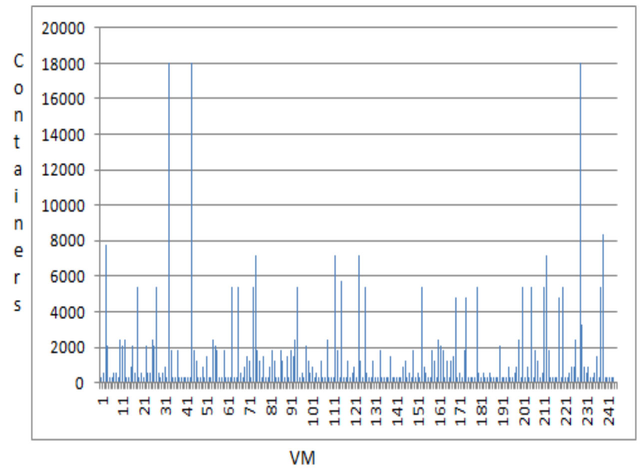

Fig. 5.2 Container Overbooking (MostFull)

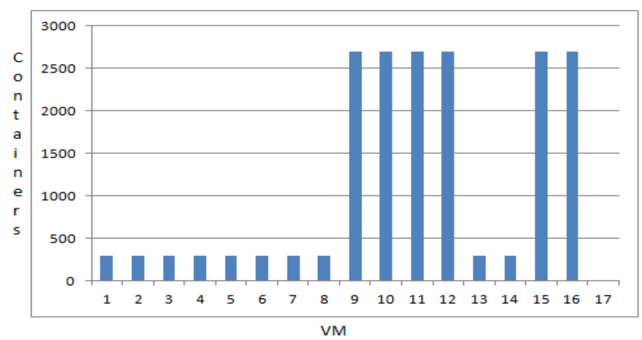

Fig. 5.3 Container Initial Placement (FirstFit)

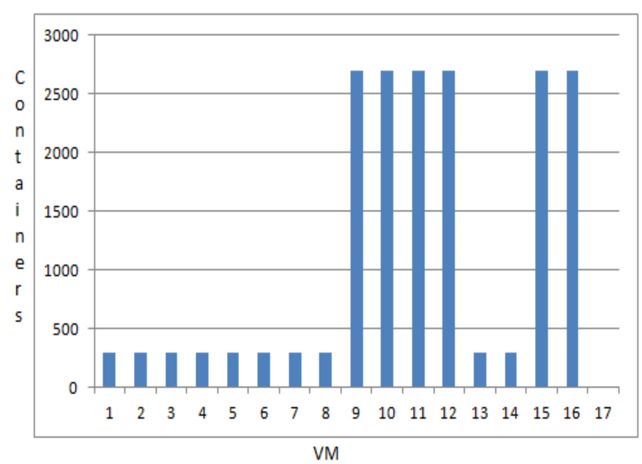

Fig. 5.4 Container Initial Placement (MostFull)

Figure 5.3 and 5.4 states that how containers which are in overbooking condition are initially placed onto another host. Based on the figure we can say that container migration rate for FirstFit algorithm is less than MostFull algorithm. The most full container placement algorithm packs containers on most full most full virtual machine in terms of CPU utilization, results in higher container migration rate. Consequently it results in higher violation and energy consumption.

VI. CONCLUSION

ContainerCloudSim is a framework which used to enquire the execution of container placement algorithms on number of container migrations, data center total power consumption and SLA violations and for implementing energy efficiency techniques. In this work we design the container overbooking for FirstFit and MostFull container allocation policy and Container initial placement policy for FirstFit and MostFull. The work suggests that the designed strategy is helpful for improving efficiency of energy in cloud data centers. This algorithm checks the hosts which are over-loaded and store them into container migration list. Then it checks for hosts which are free. In the next work we will use container consolidation technique with the combination of container overbooking and container placement policies for improvement in energy efficiency at cloud data centers.

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