A SURVEY OF VM ALLOCATION AND MIGRATION ALGORITHMS FOR ENERGY-EFFICIENT DATA CENTER

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Abstract— With the increase in usage of cloud service providers and their services, an exponential increase in the energy consumption in data centers is observed. This has lead to the increased generation of heat leading to the usage of cooling systems and large amount of electricity consumed by data centers. There is a need for energy efficient processing at data centers and power aware ways to place virtual machine (VM) requests into available computing servers to reduce energy consumption which has become a hot research subject. This survey explores the various energy efficient virtual machine allocation and migration algorithms in a cloud environment.
Index Terms— Energy-efficient, Load-balancing, Power-aware, VM allocation, VM migration, Data center

Introduction
Cloud computing is a computing platform that allows users to acquire and release resources dynamically and be charged on a pay per use basis using browser and an internet connection[9]. It provides data access, software, storage services and computation as services to the consumers through Internet. Cloud computing services provided to the consumers are classified as Infrastructure as a service (IaaS), Platform as a service (PaaS) and Software as a service (SaaS). Due to these features it is predicted to be dominant in the whole IT industry. With the growing demand of cloud, the cloud service providers are deploying large number of data centres that consume high amount of electricity.

To lower the consumption of energy in data centers is complicated and challenging. The computing applications and their data are increasing exponentially and hence larger servers and higher configuration of computing resources are required to process them within the time period agreed on in Service Level Agreement. The drastic fluctuation of workload makes data centers energy inefficient [1]. Large amount of resources are required during peak hours while many resources are idle during normal hours. This gap inversely affects system elasticity and energy saving. Low utilization of resources in a data center is the main cause of power inefficiency in data centers.

Green computing is the use of resources taking into account the environment. It involves employing energy efficient CPU and decreased consumption and disposal of electronic waste[2]. This involves manufacturing and disposing off of resources such as computers, servers, monitors, printers, network communication devices and storage devices with least impact to the environment. Green Computing is employed to manage data center resources energy efficiently.

Cloud data centres make use of the technology known as virtualization which make it possible to share the physical resources of server between various virtual machines [3]. It provides the flexibility to configure various virtual machines, on the same physical machine. Multiple VMs can be initiated and terminated on a single host dynamically. Every VM has its own characteristics and consumes different amount of energy depending upon the usage of resources and thus produce different carbon footprint. Energy aware management of virtual machines on server in a cloud data center can lead to reduction in power consumption. In other words, allocation of virtual machines on servers using green computing principles, in a cloud data center will lead to energy efficiency and reduction in power consumption.

BACKGROUND

There are mainly two techniques that are basis of energy efficiency in a cloud environment: (1) Dynamic Power Management (DPM): Keep maximum servers idle without affecting the quality of service (QoS). It is observed that an idle server consumes around 70% of its peak power hence there is a need to increase the number of idle servers without adversely affecting the QoS. This waste of power is considered as a major cause of energy inefficiency. This is where DPM comes into play. (2) Dynamic Voltage and Frequency Scaling technology (DVFS): Adjust hardware performance and power consumption to match the corresponding characteristics of workload. It is an accepted technique to reduce power and energy consumption of microprocessors. On reducing the operating frequency power consumption is reduced but the energy consumption remains unchanged because the computation needs more time to finish. Reducing the supply voltage can reduce a significant amount of energy. Reducing the supply voltage and operating frequency reduces the power and energy consumption further. Most energy-aware scheduling solutions attempt to employ DPM and DVFS for energy efficiency [11]. For each data centre two thresholds are set, the upper and lower threshold. Upper threshold is the maximum CPU utilization that can be tolerated by a server above which some virtual machines have to be migrated. The lower threshold is the minimum CPU utilization that a server should have else all virtual machines are migrated from the server and it is shut off to reduce energy consumption. Allocation of VM to a host is known as VM allocation/VM placement. Hardware resources i.e. VM can be moved from one host (Physical Machine) to another which is known as VM migration. Both VM allocation and migration if done keeping DPM and DVFS in mind lead to energy efficient cloud environment. This threshold policy is used by many data centres as the basis of virtual machine allocation and migration to obtain an energy efficient cloud environment.

There are various types of VM migration of which live VM migration is the most energy efficient. Live migration of VMs is done for power consumption, resource requirement [10]. It separates the concerns of hardware and software and also provides load balancing, low-level system maintenance and fault management.

Therefore, VM allocation and migration techniques can be useful for saving energy and thus reducing carbon emission rate. In this paper, we study the various energy efficient techniques to cloud computing that involves allocation of virtual machine to minimum number of hosts to switch off idle hosts to reduce energy consumption.

ENERGY EFFICIENT VM ALLOCATION AND MIGRATION ALGORITHMS

In order to portray various levels of performance isolation and to simulate different load balancing strategy, two virtual machine scheduling model is used which are: (1) The host level and (2) The virtual machine-level. The host level can specify host processing power allocated to virtual machines in each core. At virtual machine level, it is the amount of processing power for one unit of task that hosts on waiting queue of the level. During the process of VM migration, the user first submits jobs to cloud computing environment on any one server, the system immediately deploys user requests to the appropriate server and on the basis of the server's load conditions, and the server to complete user's tasks is decided. To achieve appropriate load balancing, cloud data centre dynamically migrate and deploy virtual machine to meet user's needs. Various algorithms have been formulated for employing an energy efficient cloud environment. Some of them have been discussed in detail in this section:

A. Modified Best Fit Decreasing (MBFD):

This is one the simplest algorithm for VM allocation on servers in cloud data center.

The input to the algorithm is a list of VM and a list of hosts. First, the virtual machines are sorted in the non-increasing order of utilization. For each virtual machine, check through all hosts for the following conditions:

(1) If hosts has enough resources for functioning the current VM then estimate the power generated by that host for the current VM.

(2) If the generated power is less than maximum power, the current VM is allocated to the considered host. The allocation of VM to a host is done such that there is least increase in the power consumption.

B. VM Migration:

The optimization of the current VM allocation is carried out in two steps: (a) select VMs that need to be migrated and (b) selected VMs have to be placed on hosts using MBFD algorithm. Double threshold VM selection policy is used for selecting VM that has to be migrated [4]. The idea is to set an upper and lower utilization threshold and keep the CPU utilization of the host between these two threshold levels.

The virtual machine are sorted in the non-increasing order of CPU utilization. For every virtual machine check the two conditions below: (a)

Difference between upper utilization threshold and CPU utilization of the considered host should be less than the utilization of the current virtual machine. (b) If the considered virtual machine is migrated then the difference between host utilization and upper utilization threshold should be minimum amongst values provided by all VM. If above two conditions are not satisfied, virtual machine with the highest CPU utilization for migration is selected and hence removed from the virtual machine list of the current host.

C. Energy-efficient and QoS-aware Virtual Machine Placement (EQVMP):

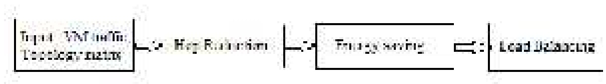

Figure. 1. Overall EQVMP algorithm

As seen in Figure. 1. The input to the algorithm is VM resource demands, VM traffic and topology matrix [5]. There are 3 steps in the algorithm: (1) Hop reduction, (2) Energy saving, (3) Load balancing. The output of the algorithm is energy efficient and quality of service aware VM placement. The steps in the algorithm are explained in detail below:

Step 1) Hop reduction

Hop reduction is used to partition virtual machines into groups based on collected traffic loads and data center topology, such that each group is balanced and the cost between groups in minimum.

Step 2) Energy Saving

This step involves energy-efficient placement of virtual machines. Steps performed in this stage are:

(1) All virtual machines are sorted in the non-increasing order of required resource demand.

(2) For each server that has been switched on select a set of candidate VMs which can fit in it.

(3) The virtual machine with minimum remaining resources is selected for the current server.

(4) If there is no VM in the set, it implies that none of existing servers has capacity to host VMs. An additional server has to be powered on to run for further iteration rounds.

Step 3) Load Balancing

This step involves detection of the over-utilized links in the network and provides an alternative path to reduce congestion. It balances the network. In SDN data center, flows to different routing paths for the same source and destination are assigned by the controller. The utilization of every link in data center is monitored by controller. As soon as the controller detects that a particular link has reached the threshold, like 85 % of the maximum capacity, it will immediately assign another low utilization path and move certain portion of flows on it to balance the traffic. Every time a VM is added or removed this step is executed.

D. Energy and Carbon Efficient VM Placement and Migration Technique:

Data centers distributed over various geographic locations have their own carbon footprint rate depending on their energy resource. The carbon footprint of the Cloud for a time interval [*0,t*] with *d* datacenters having *c* number of clusters each, and each cluster having *h* number of hosts is calculated as in following equation [6]:

$$CF = \sum_{t=1}^{T}\sum_{i=1}^{d}(PUE_i \times \sum_{j=1}^{c}(cf_j \times \sum_{k=1}^{h}(P(vm_{i,j,k,t} \times ht))))$$

Where, CF is the carbon footprint of the cloud, *PUE* indicates power usage effectiveness and is described as the ratio of datacenter's total power consumption to the power consumption by the IT devices and ht represents Holding time for VM *vm*.

Step 1) VM Allocation:

When a cloud broker receives a new VM request it checks the centralized database of all data centers which is present with the broker. This database contains the details of the carbon footprint rate of each data center. The broker than selects the data center that is most carbon efficient. For the selected data center a list of hosts is made that fulfil the requirement of the VM. If there is a single host in that data center, the host is allocated for the VM request. If there is more than one host in the selected data center, the host with the maximum CPU utilization is selected.

The VM allocation algorithm takes into consideration the carbon footprint of the data center to obtain energy efficiency.

Step 2) VM Migration:

This step is performed to reduce the energy consumption within each data center. The virtual machine is migrated to other host if the CPU utilization of current host is lesser than the lower utilization threshold or greater than upper utilization threshold. The steps for VM migration are:

(1) The VM is selected for migration process and

(2) The selected VM is placed in the appropriate host. It selects the minimum number of virtual machines to be migrated such that CPU utilization of a host is above the upper utilization threshold. It also selects all the VMs from a host having utilization below the lower threshold. For placement of the selected VM for migration, Modified Best Fit Decreasing algorithm is used.

PERFORMANCE EVALUATION OF ALGORITHMS

A. MBFD and Migration algorithm:

The modified Best fit decreasing and migration algorithm when applied on a static number of VMs and hosts leads to 45% reduction of energy consumption in comparison to running hosts on 100% CPU utilization. This experimentation was done on CloudSim framework. CloudSim[7] is a framework for Modeling and Simulation of Cloud Computing Infrastructures and Services. It is the most popular cloud simulation tool that is open-source and implemented in Java.

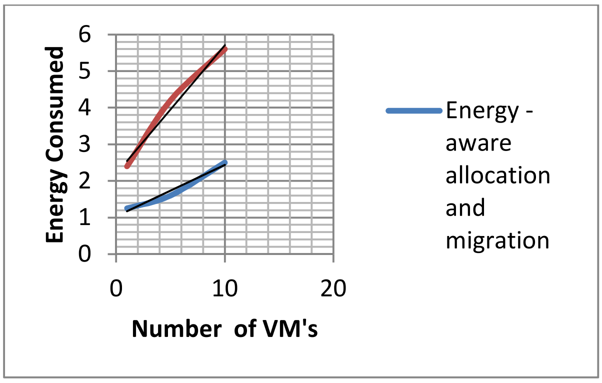

Figure. 2. Energy aware allocation and migration vs Non energy aware

B. EQVMP:

The experiment has two steps. First determine how to arrange VMs on servers such that energy is saved and reduction of hop count. Second to implement VM placement algorithm on the simulation tool to observe the performance of network. To compute virtual machine allocation setting java programming was used and NS2 was used as simulation tool. NS2 stands for Network Simulator 2. It is an open-source simulation tool that runs on Linux [8]. It is a discreet event simulator targeted at networking research and provides substantial support for simulation of routing, multicast protocols and IP protocols, such as UDP, TCP, RTP and SRM over wired and wireless (local and satellite) networks.

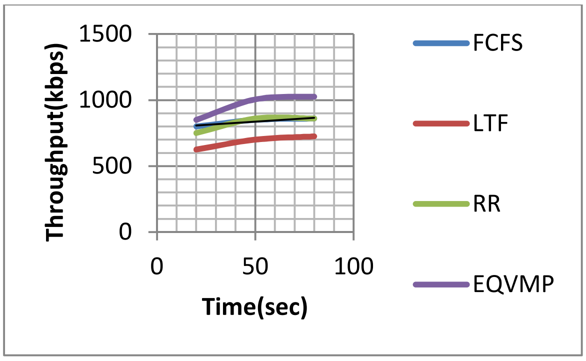

Figure. 3. Comparison various VM placement policies with EQVMP

Figure. 3. illustrates the comparison of various VM placement policies with EQVMP. EQVP is compared with old VM allocation methods such as First Come First Serve (FCFS), Largest Task First (LTF) and Round Robin (RR). FCFS involves allocation of VM in the order of arrival. For better resource utilization, LTF is used. LTF is to allocate VMs with heavy resource demand on the same server without SLA violation. RR employs fairness in networks ,therefore, VMs are equally placed among servers. LTF has the lowest throughput while EQVMP gives the maximum throughput. FCFS and RR have approximately same throughput as the time progresses.

C. Energy and Carbon Efficient VM Placement and Migration Technique:

This technique is about 30% efficient as compared to non-power aware methods since it takes into account carbon footprint and also picks up the data center that is closest and with minimum energy consumption.

CONCLUSION

Energy efficient cloud environment is the need of the hour and there are various steps that are being taken to reduce the power and energy consumption of data centers associated to cloud. Designing power- aware virtual machine allocation and migration techniques lead to significant reduction in power consumption in data centers. Employing Green Computing in cloud advances the Cloud computing fields in two ways: First, it plays a significant role in reducing power and energy consumption that reduces operational cost as well. Second, consumers are now becoming conscious of the environment.

The algorithms included in this study all make the cloud environment energy and power aware. MBFD and Migration algorithm are the most basic algorithms as the others employ some principles of MBFD for VM allocation. If we compare these algorithms, EQVMP is the most efficient as it increases the throughput while saving energy, reducing hop count and load balancing. Energy and Carbon Efficient VM Placement and Migration Technique selects the data center which is closest which has enough resources to service the VM request and further finds the best server in that data center. It can also be used for Grid computing.

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