J. of Ultra Comp. and I.T. Vol. 7(1), 7-13 (2016). ISSN 2229-3531 (Print)
www.compitjournal.org 2455-9997 (Online)

A Survey Report on VM scheduling and Consolidation in Cloud Computing

RAKESH KUMAR VISHWAKARMA[1], SYED IMRAN ALI[2] and ANIDRA KATIYAR[3]

[1]Computer Science Engineering Sagar Institute of Science, Technology and Research Bhopal (India)
rakeshvishwakarma045@gmail.com
[2]HOD,CSE Sagar Institute of Science, Technology and Research Bhopal (India)
talktoimranali@gmail.com
[3]Assistant Professor
Sagar Institute of Science, Technology and Research Bhopal (India)
ani_katiyar@rediffmail.com

(Acceptance Date 4th August, 2016)

Abstract

Cloud Computing is extremely new and helpful technology for networking world, it functions to cut back electronic waste and dealing setting in virtual platforms and centralized information storage options, it's terribly advanced and new properties for storage, computer code readying and net primarily based platform services that helps lots to manage network setting in easiest method with safety features. To store data centrally VM placement MBFD technique is very new, and advanced technology which helps in cloud energy minimization. This paper presents a brief survey onVM scheduling and Consolidation in Cloud Computing.

Key words : Cloud Computing, VM Scheduling, mbfd,energy minimization, server consoidation, resource optimization.

I. Introduction

This paper presents the state of the art literature survey in the field of VM scheduling and consolidation in cloud computing which has been carried out by surveying through various journals and articles. This paper deals with the study and analysis of virtual machine scheduling algorithms used for effective management of cloud data centers. We will identify the research gap and formulate the research problem for the dissertation work.

Cloud Computing belong to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that consume those services. The services themselves have long been inserted to as Softwareas a Service (SaaS)[10], their technical report contributed the following aspects of cloud:

- Definition and understanding of cloud computing and how it is distinct from already existing utility computing and SaaS platform.
- Opportunities in the field of cloud computing for cloud service provider and consumers.
- The new economic models enabled by Cloud Computing, and how can a service operator decide whether to move to the cloud or stay in a private datacenter.
- What are the top 10 obstacles to the success of Cloud Computing and the corresponding top 10 opportunities available for overcoming the obstacles.

Cloud computing is an inevitable technology paradigm for IT organizations in delivering their services to the customers.

A. Energy Efficiency in Data Centers

The recently developed models and algorithms for energy efficient resource allocation in Cloud data centers aim to propose, develop and evaluate optimization algorithms of resource allocation for traditional Infrastructutre as a Service (IaaS) architectureslike in[2] the authors investigated two exact energy-efficient Virtual Machine scheduling algorithms to achieve an optimal VM management comprising optimal placement and migration of VMs. First they propose an exact VM allocation algorithm which is an extension to Bin Packing approach with some constraints imposed on it. Followed by this, the Best-Fit heuristic[25] is being used for good sub-optimal performance. The VM migration is done based on integer linear program (ILP) to reduce the span of migration problem. They implemented to observe considerable energy savings done by exact Bin-Packing algorithm, depending upon the system load. However, intelligent rearrangements and re-optimization, if used, could have increased the performance to a much higher level.

R. Buyya *et al.*[21] spotlighted on the synergism between the various data center infrastructures to boost up their performance and energy efficiency. The paper proposed: (1) Quintessential architectural principles (2) Resource allocation and scheduling policies based on Bin Packing problem to meet QoS (Quality of Service) requirements (3) A novel software technology that aims at building a strongly competitive cloud computing industry. The validation of proposed work using CloudSim was quite convincing and supporting in development of dynamic resource management algorithms.

II. Literature Work:

As discussed earlier, dynamic server consolidation can improve the energy efficiency by optimum utilization of resources and aims to reduce the number of active physical machines in the data center.

A. Server Consolidation Steps:

To solve the complex problem of dynamic server consolidation and to provide decentralization, it has been divided into four main events or steps[19] discussed as follows:

1) Host Overload Detection
2) Host Under-load Detection
3) VM Selection and Migration
4) VM Placement

1) ***Host Overload Detection:*** The scheduling technique must set a threshold limit in order to decide when a certain host/server is over-utilized. This limit can be termed as *'Hot Threshold'* and when this limit is crossed, such a server is said to be a hot-spot and some of this host's VMs need to be migrated to other hosts,[27].

An Adaptive Utilization Threshold: In[24] authors Anton Beloglazov and Rajkumar Buyya proposed a heuristic for deciding the time to migrate VMs from a host based on utilization thresholds. The main idea of the proposed adaptive-threshold algorithms is to adjust the value of the upper utilization threshold depending on the strength of the deviation of the CPU utilization. The higher the deviation, the lower the value of the upper utilization threshold, as the higher deviation, the more likely the CPU utilization will reach 100% and cause an SLA violation[19].

Local Regression:In[19] authors Anton Beloglazov et al. base the main idea of the method of local regression is ûtting simple models to localized subsets of data to build up a curve that approximates the original data.

2) ***Host Under-load Detection****:* If a certain server is under-utilized, *i.e.* it has reached below the *'Cold Threshold'* (a scenario just opposite to host overload) it is said to be a cold-spot and the aim of server consolidation is to identify that server and migrate all of its virtual machines to other active hosts,[13]. Thus the under-utilized server is freed up & it can be switched to sleep/idle mode to save power.

In[19] for determining under-loaded hosts authors propose a simple approach. First, all the overloaded hosts are found using the selected overload detection algorithm, and the VMs selected for migration are allocated to the destination hosts. Whereas in[11,16,17] authors considers from their studies that if the CPU utilization is lower than 30% then lower threshold is always 0.3 and all the VMs have to be migrated from this under-loaded host.

Mitigation of Hot and Cold Spots: The detection of hotspots and cold spots are always based on thresholds, the former implies over-utilization and the latter implies underutilization, applicable across any resource dimension.[9, 11, 13, 15, 17] are some of those works which address hostspot and cold spot mitigation while consolidation and load balancing.

3) ***VM Selection and Migration**:* Appropriate candidates (VMs) are selected either from overloaded or under-loaded host for migration. The following VM selection policies exist in literature:

VM Selection Policies for Placement Optimization:

The Minimum Migration Time Policy: The Minimum Migration Time (MMT) policy performs migration of a VM that requires the minimum time to complete a migration relative to other VMs allocated to the host. The migration time is estimated as the amount of RAM utilized by the VM divided by the spare network bandwidth available for the host[19]. Let V_j be a set of VMs currently allocated to the host *j*. A VM *v* satisfying the understated conditions is found by the MMT policy in (1):

$$v \in Vj | \forall a \in Vj, \frac{RAM_u(v)}{NET_j} \leq \frac{RAM_u(a)}{NET_j} \quad (1)$$

The Random Choice Policy: The Random Choice (RC) policy selects a VM to be migrated according to a uniformly distributed discrete random variable X, whose values are indexed to set V_j [19].

The Maximum Correlation Policy: The Maximum Correlation (MC) policy is based on the idea that higher the correlation between the resource usage by applications running on an oversubscribed server, the higher the probability of the server overloading. According to this idea, authors Anton Beloglazov et al. in[19] select those VMs to be migrated that have the highest correlation of the CPU utilization with other VMs.

Minimum Utilization: The Minimum Utilization (MU) policy selects a VM to migrate whose CPU utilization is less compared to other VMs available on the host.

VM Migration Techniques for Placement Optimization:

Das[18] describes all the algorithms that attempt to efficiently allocate resources on-demand through live migration answers four questions:- (1) determining when a host is considered as being overloaded requiring migration of one or more VMs from this host; (2) determining when a host is considered as being under-loaded leading to a decision to migrate all VMs from this host and switch the host to the sleep mode; (3) selection of VMs that should be migrated from an overloaded host; and (4) finding a new placement of the VMs selected for migration from the overloaded and under loaded hosts. Following table1 describes them concisely:

Table 1: Virtual Machine Migration Heuristics

Goals	Server Consolidation	Load Balancing	Hotspot Mitigation
When to migrate? on PMs	Cold-spots on PMs	Load Imbalance	Hotspots on PMs
Which VM to Migrate?	VMs from Lightly Loaded PMs	VMs from overloaded PMs	Bunch of VMs from hotspot-PM
Where to Migrate?	Higher loaded PMs	Lightly loaded PMs	PM which has enough resources to house

K. Li *et al.*[14], broadly categorized VM placement into two methods, namely Direct placement and Migration-based placement, based on the fact that the time taken to complete a job depends upon the type of VM placement. In consideration of this NP-Hard problem, they proposed an MBVMP algorithm for VM placement.

4) ***VM Placement**:* The VM(s) selected in previous step is then placed on some other physical machine according to a suitable VM to PM mapping criteria[29]. With the help of live migration of VMs, Server Consolidation aims at achieving—least possible number of Active physical machines, packing these Active PMs with VMs as tightly as possible to

increase energy efficiency and switching the non active PMs to a power saving mode.

Virtual Machine Placement Techniques in Cloud Data Centers:

Virtual Machine placement is the process of selecting the most suitable Physical Machine (PM) for a given Virtual Machine (VM). So a VM placement algorithm aims at determining the most optimal VM to PM mapping whether it is an initial VM placement or a VM migration for placement re-optimization. The placement technique in VM consolidation can have one of the two goals—one is power saving and other is delivering QoS. The type of VM placement approach varies from a cloud service provider to another.

- **Classification of VM Placement Algorithms :** Depending on the *goal* of placement, a VM placement algorithm can be broadly categorized into two types:

1) ***Power-based approach**:* Aims to waste a VM-PM mapping which results into a system that is energy-efficient with group resource utilization[1,13]. It is done in such a manner that the servers can be utilized to their maximum efficiency, and the other servers can be either sleep or shut down depending on load conditions.
2) ***QoS-based approach**:* Aims to obtain a VM-PM mapping to ensure maximal fulfillment of quality of service requirements[7, 27, 28]. By continuously monitoring virtual machine activity and employing advanced policies for dynamic workload placement, such algorithms can lead to better utilization of resources and less frequent overload situations eventually leading to savings in cost.

- **Classification of VM Placement Algorithms:** Depending on the type of *migration technique* used to attain a desirable VM-PM mapping, VM Placement techniques are mainly classified as depicted in figure 2.1 as explained below:

1) Constraint Programming: It is a kind of logic programming, as a contrast to mathematical approaches, to solve complex combinatorial problem of optimal VM placement. It uses a set of constraints which can easily be extended further to involve more aspects. *Zhang et al.*[26] proposed a virtual cloud resource allocation model based on constraint programming (VCRA-CP), capable of meeting goals of Quality of Service requirements and reducing the cost of resource usage. The authors took into account the performance fulfillment goals of applications and workload types. Dupont *et al.*[29] introduced a flexible and extensible framework which is based on the VM Repacking Scheduling Problem (VRSP) for energy-aware resource allocation in data centers considering SLA constraints to perform VM placement. This approach allows the user to automatically derive the SLA constraints and lowers energy usage.

Ghribi *et al.*[2] investigated two exact energy-efficient algorithms to achieve optimal placement and migration of VMs. First they propose an exact VM allocation algorithm which is an extension to Bin Packing approach with some constraints imposed on it. Followed by this, the Best-Fit heuristic[7] was used for good sub-optimal performance. The VM migration is done based on integer linear program (ILP) to reduce the span of migration problem. However, intelligent rearrangements and re-optimization, if used, could have increased the performance to a much higher level.

2) Bin Packing: The classical problem of Bin packing consists of a series of items having sizes specified in the interval (0, 1] which need to be packed into least possible number of bins with capacity one. To model this problem as a resource allocation algorithm, we consider each item as a Virtual Machine (VM) to be tightly packed in minimum number of bins, each considered as a Physical Machine (PM). The bin packing problem is NP hard. The quality of a polynomial time approximation algorithm A, is measured by its approximation ratio, R (A) to optimal algorithm, OPT as formalized in (2):

$$R(A) = \lim_{n\to\infty} sup_{OPT(L)=n} \frac{A(L)}{OPT(L)} \quad (2)$$

where, A (L) is the number of bins used under the algorithm A, OPT (L) is the number of bins used under the optimal algorithm OPT and L is the list of input sequence. In this section we throw some light on the existing VM scheduling techniques which aim at improving server consolidation using Bin Packing approach.

W. Song et al.[1] formulated a dynamic resource allocation algorithm based on Bin packing which optimizes the number of actively running servers. They designed a slight variation of the Relaxed Online Bin Packing algorithm[5] and named it as VISBP (Variable Item Size Bin Packing). They implemented it using extensive trace-driven simulation and also compare it with three well known server consolidation algorithms: the Black Box & Gray box algorithm[12], the Vector Dot algorithm[1] and the Offline-Bin Packing algorithm[6]. The core of VISBP is its ability to handle the change in size of an item (VM) at runtime. This "change" operation supports an on demand, dynamic resource allocation. VISBP excels in load balancing and hot-spot detection but it violates service level agreements to an extent and there is need to improve the VM to PM ratio.

Y. Zhang et al.[4], addressed the problem that the existing Bin packing heuristics, whether single dimensional or multi-dimensional, do not dig much into the resource requirement heterogeneity of VMs. So they proposed heterogeneity aware algorithms like DRR-FFD (Dominant-Residual Resource aware FFD) and its variations. With a little struggle in clustering VMs based on their dominant resources, the proposed algorithms achieve a performance similar to multi-dimensional algorithms.

A. Alahmadi et al.[3], give a novel scheduler approach which lays more focus on the reuse of VMs and uses a modification of First-Fit Decreasing algorithm *i.e.* Enhanced FFD united with VM reuse scheme. This kind of strategy guarantees execution within expected time and yields high throughput

3) Stochastic Integer Programming: In contrast to logical approach, this is a mathematical optimization technique in which the future demands are uncertain. They make use of estimation models using probability distributions of the concerned data. Here, the future demand of a VM or an application is unknown and therefore, some VM placement techniques use this approach to predict the suitable VM-PM mapping.

N. Bobroff et al.[7], devised a dynamic server consolidation and migration algorithm which decrements the SLA violation rate and reduces the capacity demands of servers, thereby curtailing data center running costs. The algorithm operates in three major steps- (1) Measuring historical data (2) Forecasting the future demand (3) Remapping VM to PM, and therefore it is referred to as Measure-Forecast-Remap (MFR) algorithm.

M. Wang et al.[8] formulated a Stochastic Bin Packing problem by studying how the network devices like switches and Ethernet adapters should impose a certain limit on the network bandwidth when the VMs are consolidated. They predicted bandwidth usage in future through a probabilistic characterization. The proposed an NP-Hard problem, Group Packing which made use of Gaussian distributions.

Speitkamp et al. [23] provided a mathematical formulation of the NP-Hard Optimization problem for server consolidation making use of an LP-relaxation-based heuristic and historical workload analysis. They extended the SSAPv and DSAP decision models explained in[32], applying a number of constraints to minimize the servers' operational and other costs. This capacity planning approach uses an optimization model along with a data preprocessing approach to achieve optimal placement.

4) Genetic Algorithm: Beinga part of evolutionary computation, it performs natural selection of suitable solution from all possible solutions. This heuristic can be called as bin packing extended with additional constraints.

Mi et al.[22] propose a Genetic Algorithm Based Approach (GABA) which follows an adaptive self-reconfiguration of VM reallocation on heterogeneous PMs. It can search for optimal solutions online. To catch up with the changing workloads, request forecasting module is used. GABA results in conservation of power and deals with multi-objective optimization.

Ferdaus et al.[20] model the problem of VM placement as an NP-Hard Multi-Dimensional Vector Packing Problem (mDVPP) focusing on balancing the cloud resource utilization, making use of the ACO (Ant Colony Optimization) metaheuristic. This is an effective approach where computation time is also remarkably lesser.

Conclusion

The paper provides a detailed summary of above discussed and reviewed VM placement algorithms by comparing their basic attributes like— the standard

VM placement technique on which they are based, the number of resources used (likeCPU, memory and bandwidth), their achieved goals, future enhancements and lastly, those algorithms which they outperform.To catch up with the changing workloads, cloud providers need to inculcate more dynamic schemes to manage the data center servers. The paper delved with the detailed taxonomy of VM scheduling and consolidation techniques elaborating upon their pros and cons. There is still more scope of further improvement in the above reviewed algorithms so as to achieve minimal carbon footprints and more and more energy efficiency.

References

1. Song, Weijia, et al. "Adaptive resource provisioning for the cloud using online bin packing." *Computers, IEEE Transactions on* 63.11, 2647-2660 (2014).
2. Ghribi, Chaima, Makhlouf Hadji, and Djamal Zeghlache. "Energy efficient vm scheduling for cloud data centers: Exact allocation and migration algorithms." *Cluster, Cloud and Grid Computing (CCGrid), 2013 13th IEEE/ACM International Symposium on*. IEEE, (2013).
3. Alahmadi, Ahmed, *et al*. "Enhanced First-Fit Decreasing Algorithm for Energy-Aware Job Scheduling in Cloud." *Computational Science and Computational Intelligence (CSCI), 2014 International Conference on*. Vol. *2*. IEEE, (2014).
4. Zhang, Yan, and Nayeem Ansari. "Heterogeneity aware dominant resource assistant heuristics for virtual machine consolidation." *Global Communications Conference (GLOBECOM), 2013 IEEE*. IEEE, (2013).
5. Gambosi, Giorgio, Alberto Postiglione and Maurizio Talamo. "Algorithms for the relaxed online bin-packing model." *SIAM journal on computing* 30.5 1532-1551 (2000).
6. Bobroff, Norman, Andrzej Kochut, and Kirk Beaty. "Dynamic placement of virtual machines for managing sla violations." *Integrated Network Management, 2007. IM'07. 10th IFIP/IEEE International Symposium on*. IEEE (2007).
7. Rieck, Bastian. "Basic Analysis of Bin-Packing Heuristics." *Publicado por Interdisciplinary Center for Scientific Computing. Heildelberg University* (2010).
8. Wang, Meng, Xiaoqiao Meng, and Li Zhang. "Consolidating virtual machines with dynamic bandwidth demand in data centers." *INFOCOM, 2011 Proceedings IEEE*. IEEE, (2011).
9. Singh, N. Ajith, and M. Hemalatha. "Energy efficient virtual machine placement technique using banker algorithm in cloud data centre." *Advanced Computing and Communication Systems (ICACCS), 2013 International Conference on*. IEEE, (2013).
10. Armbrust, Michael, *et al*. "A view of cloud computing." *Communications of the ACM* 53.4, 50-58 (2010).
11. Girish Metkar, Sanjay Agrawal, Dr. Shailendra Singh. A Live Migration of Virtual Machine based on Dynamic Threshold in a Cloud Data Centers. In: International Journal of Advanced Research in Computer Science and Software Engineering (2013).
12. Wood, Timothy, *et al*. "Sandpiper: Black-box and gray-box resource management for virtual machines." *Computer Networks* 53.17, 2923-2938 (2009).
13. Beloglazov, Anton and Rajkumar Buyya "Adaptive threshold-based approach for energy-efficient consolidation of virtual machines in cloud data centers."*Proceedings of the 8th International Workshop on Middleware for Grids, Clouds and e-Science*. Vol. 4. ACM (2010).
14. Li, Kangkang, Huanyang Zheng, and Jie Wu. "Migration-based virtual machine placement in cloud systems." *Cloud Networking (CloudNet), 2013 IEEE 2nd International Conference on*. IEEE, (2013).
15. Xiao, Zhen, Weijia Song, and Qi Chen. "Dynamic resource allocation using virtual machines for cloud computing environment." *Parallel and Distributed Systems, IEEE Transactions on* 24.6, 1107-1117 (2013).
16. Anton Beloglazov and Rajkumar Buyya. Energy Efficient Allocation of virtual Machines in Cloud Data Centers. In: 10th IEEE/ACM Intl. Symp. On Cluster, Cloud and Grid Computing (2010).
17. Richa Sinha, Nidhi Purohit, Hitesh Diwanji. Power Aware Live Migration for Data Centers in Cloud using Dynamic Threshold In: International Journal of Computer Technology and Applications, December, Vol. 2 (2011).
18. Anwesha Das dissertation on A Comparative Study of Server Consolidation Algorithms on a Software Framework in a Virtualized Environment submitted to IIT Mumbai.
19. Beloglazov, Anton, and Rajkumar Buyya. "Optimal online deterministic algorithms and adaptive heuristics for energy and performance efficient dynamic consolidation of virtual machines in cloud

data centers." *Concurrency and Computation: Practice and Experience* 24.13, 1397-1420 (2012).

20. Ferdaus, Md Hasanul, *et al.* "Virtual machine consolidation in cloud data centers using ACO metaheuristic." *Euro-Par 2014 Parallel Processing*. Springer International Publishing, 306-317 (2014).
21. Buyya, Rajkumar, Anton Beloglazov, and Jemal Abawajy. "Energy-efficient management of data center resources for cloud computing: a vision, architectural elements, and open challenges." *arXiv preprint arXiv: 1006.0308* (2010).
22. Mi, Haibo, *et al*. "Online self-reconfiguration with performance guarantee for energy-efficient large-scale cloud computing data centers." *Services Computing (SCC), 2010 IEEE International Conference on*. IEEE, (2010).
23. Bichler. "A mathematical programming approach for server consolidation problems in virtualized data centers."*Services Computing, IEEE Transactions on* 3.4, 266-278 (2010).
24. Beloglazov, Anton, Jemal Abawajy, and Rajkumar Buyya. "Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing." *Future generation computer systems* 28.5, 755-768 (2012).
25. Tao, Fei, *et al*. "BGM-BLA: a new algorithm for dynamic migration of virtual machines in cloud computing." (2015).
26. Zhang, Long, Yi Zhuang, and Wei Zhu. "Constraint Programming based Virtual Cloud Resources Allocation Model." *International Journal of Hybrid Information Technology* 6.6, 333-344 (2013).
27. Beloglazov, Anton, and Rajkumar Buyya. "Managing overloaded hosts for dynamic consolidation of virtual machines in cloud data centers under quality of service constraints." *Parallel and Distributed Systems, IEEE Transactions on* 24.7, 1366-1379 (2013).
28. Beloglazov, Anton, and Rajkumar Buyya. "Energy efficient resource management in virtualized cloud data centers." *Proceedings of the 2010 10th IEEE/ ACM International Conference on Cluster, Cloud and Grid Computing*. IEEE Computer Society, (2010).
29. Dupont, Corentin, *et al*. "An energy aware framework for virtual machine placement in cloud federated data centres." *Future Energy Systems: Where Energy, Computing and Communication Meet (e-Energy), 2012 Third International Conference on*. IEEE (2012).