Energy Efficient Techniques In Virtualized Data Center: A Survey

Ankita Jiyani
Research Scholar: Computer Science & Engineering Dept.
Swami Keshvanad Institute of Technology
Jaipur,India
ankitajiyani09@gmail.com

***Abstract*— Energy efficiency simply means that how efficiently energy can be used or consumed by any virtualized datacenters providing cloud services. Main aim of energy efficiency is to reduce the amount of energy consumed or required to provide a set products and services without degrading the QoS requirements.**

Virtualization is key technology for cloud computing environment. The data centers consists of computing elements such as Virtual Machines (VM), Physical Machines (PM) or host nodes that consume huge energy amount during computation and hence, motivated industries as well as allied scientific society develops the various techniques such as VM migration, VM & Server Consolidation.

In this paper, I survey the latest Energy efficient techniques developed for cloud computing environment.

Keywords- Energy efficiency, Virtualization , Cloud Computing ,VM migration, VM & Server Consolidation.

I. INTRODUCTION

Cloud computing, has evolved during the recent decades and gaining acceptance in IT organizations and has made a significant impression as commercial computing in business world. Cloud computing platform provides an easy access to the services, like storage, computing, resources, infrastructure, software, etc which are scattered at different location, through internet and these utilities are consumed on demand by consumers[1]. The demand of the consumers is dynamic in nature, i.e. changing needs according to time[2].

Many industries are moving towards cloud computing due to its efficient services, which is provided by pay-as-you-go pattern. The user is charged according to the amount of resources consumed. Resources such as data transferred, storage space occupied, processing power used, bandwidth consumed or transactions carried out etc[1][2].

Rajkumar et. al. [3] define cloud computing as "A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers."

But due to limited availability of resources it is high priority task for CSP(Cloud Service Providers) to fulfill all the demanded services on time.

From the CSP view point, demanded services should be serve in time and the manner of allocation of resources must be fair.

From customer view point demanded services should meet its QoS requirements and must satisfy their needs.

Form energy saving view point, cloud carrier which provides access via network, should use available bandwidth efficiently.

So, it's a vital issue to meet all these specified constraints and resources should be utilized efficiently, so that profit for the CSP(s) can be maximized and cost for the consumers can be minimized.

This efficiency can be achieved by Virtualization[1][2][3].

The remainder of the paper is structured as follows: Section 2 discusses Virtualization. Section 3 gives the concept of migration. Section 4 knock around the basics of consolidation. Section 5 examines various energy efficient techniques proposed by researchers. In Section 6, a classification based on the discussed techniques in Section 5 is presented followed by the conclusion of work in Section 7.

II. VIRTUALIZATION

It is both heart and brain of cloud computing environment. This technique can be interpreted as abstraction of computer resources. It undergrounds the physical characteristics of the resources from the consumers and gives them the perspective for utilizing them as logical ones[4]. By virtualize, we mean that a single physical resource can be exposed as multiple virtual resources or multiple physical resources can be exposed as a single virtual resource. Resource can be anything like server, an OS, an application, or a storage device. The main aim of virtualization is to efficiently utilize the limited IT resources by making use of many idle resources[5].

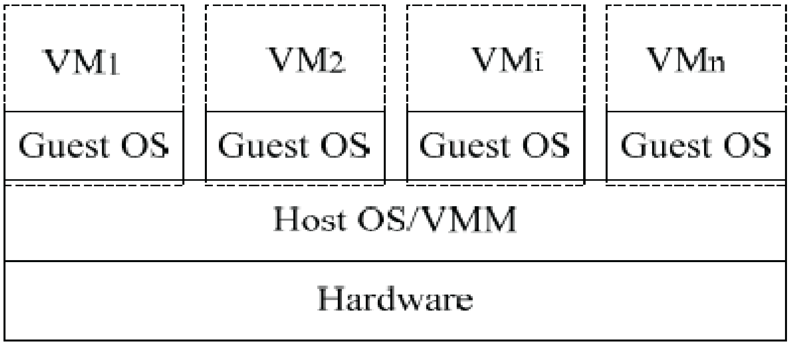

Figure 1. Virtual Machine Diagram [Ref 4]

In the architecture, one physical machine is branched into multiple virtual machines. Host OS/VMM (Virtual Machine Monitor) helps virtual machines by allocating necessary resources. The guest OS in turn provide the platform to perform required tasks by corresponding virtual machines and also providing the high level of abstractions such as file access and network support to applications running on the virtual machines[5].

The fact is, virtual machine (VM) serving as logical machine have almost the same architecture as a real host machine, along with an operating system running in it[6].

A. Benefits of Virtualization:

- Provides great flexibility(Users and Administrators).
- Allows (Users and Administrators) to create, save(checkpoint), copy, share, migrate, read & modify, & rollback the execution state of machine.
- Cost is reduced.
- Energy consumption is reduced.
- CO_2 emission is reduced.

III. THE CONCEPT OF MIGRATION

There can be scenario when one physical machine(PM) gets overloaded, so it is required to dynamically transmit a part of its load to different machine with negligible interruption to the users. This situation is termed as migration or virtual machine(VM) migration, as the whole VM is moved from one PM to another PM[7][8].

Now there can be two scenario for migrating the VM, either first we shut the VM on first PM, then move it to another required PM(services running in VM gets interrupted)[7] or we can migrate the VM over PM without shutting it down(services running in VM doesn't get interrupted)[6]. The former one is known as Non-Live or Cold migration and the later one is known as Live or Hot migration.

Cold migration has simple operation, but its service downtime is relative to the amount of allocated physical memory of VM[7].

This can be lead to an unacceptable outcome if the VM is running a live service.

There are two approaches for hot migration post copy memory migration & pre copy memory migration:

Authors in [5] define Post-copy memory migration as, "It first suspends the migrating VM at the source, copies minimal processor state to the target node, resumes the virtual machine, and begins fetching memory pages over the network from the source."

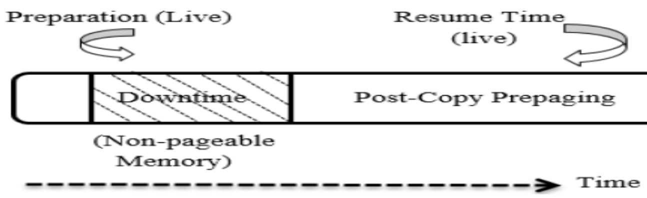

Figure 2. Post-Copy memory migration[Ref 5]

Authors in [5] define Pre-copy memory migration in two phases as,

1. Warm-up phase: In warm up VM memory migration phase, the hypervisor copies all the memory pages from source to destination while the VM is still running on the source. If some memory pages change during memory copy process—dirty pages, they will be re-copied until the rate of recopied pages is not less than page dirtying rate.
2. Stop and Copy phase, the VM will be stopped in source and the remaining dirty pages will be copied to the destination and VM will be resumed in destination.

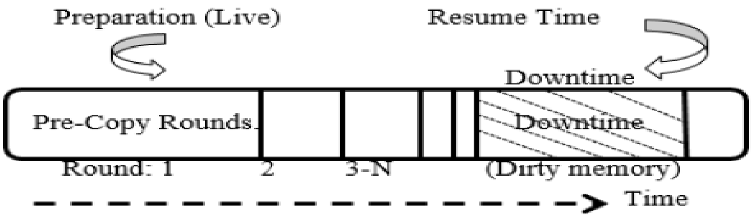

Figure 3. Pre-Copy memory migration[Ref 5]

Hot migration smoothens the process of consolidation of virtual machines, load balancing, online system maintenance, fault tolerance etc.

While migrating VM to other PM, this process will consume energy, network bandwidth & emits CO_2[8] which are important factors to be considered by any virtualized datacenter in order to achieve an efficient migration in terms of energy consumption, network bandwidth, cost and when it comes to the emission of CO_2, data centers will move to the greener side, i.e. data centers will try to adapt the environment friendly techniques for their cloud and hence green cloud computing comes into the scenario.

Green cloud computing can be defined as eco-friendly use of computing resources, so they have minimal impact on the environment[9].(full description of green cloud computing is out of the scope of this research work).

IV. THE CONCEPT OF CONSOLIDATION

VM consolidation[10] & Server Consolidation[11] comes into the scenario, when we are concerned about the energy consumption in Virtual Machine migration technique which itself means that there is low energy consumption.

Virtual Machine (VM) consolidation approach uses hot migration of VMs so that some of the under-loaded or under-utilized Physical Machines (PMs) or the PMs which are not in current use can be deactivated or switched-off or can be put into a low-power mode. And can be activated or switched-on or can be put into high-power mode when any migration to that PM occurs, PM accommodate that VM for service continuation[10]. If unsatisfactory migration occurs,QoS can be degraded.

Server consolidation approach uses several VMs. That can be grouped together or packed on a single PM, so that to allow a PM run in its most energy-efficient condition and remaining PMs can be set to an energy-saving state[11].

By doing so, desired level of QoS can be achieved, resource utilization can be maximized & significant amount of energy can be minimized in data centers[10][11].

V. LITERATURE REVIEW

N.J. Kansal, I. Chana[12] proposed an energy-aware VM migration technique based on the Firefly algorithm. This technique tries to migrate the most loaded VM (brighter VM)from an active node which satisfies a minimum criteria for energy consumption, to another active(less brighter VM) node that consumes the least energy. By using this technique, data centre make themselves more energy-aware as enhancement has been made in average energy consumption.

Y. Ding et al.[13] proposed an novel approach for energy efficient scheduling algorithm, EEVS, of VMs with deadline constraint, and EEVS support Dynamic Voltage and Frequency Scaling (DVFS). This algorithm deals with optimal frequency (frequency of PM to process VM), which is based on performance-power ratio (PPR) of PM (ratio of its computation capacity to the peak power). The PM with high computation capacity and low peak power, i.e. PM with high PPR assigned to VM to save energy.

The process of EEVS is divided into equivalent schedule periods, in each period VMs are allocated to appropriate PMs and each active core of PM operates on the optimal frequency. The cloud to be reconfigured, after each period, to consolidate the computation resources for further reduction of energy consumption. The deadline constraint must be satisfied during the scheduling.

X. Wang et al.[14] proposed a new strategy which manages power for data centers by using sustainable energy resources and making it green-aware.

They formulate an overall optimizing problem, by using energy-aware method and solve it by combined approach of heuristics and statistical searching. The ultimate goal of this paper is to utilize green energy sufficiently while keeping the demand of applications deployed inside the datacenter at an acceptable level. The simulation results show that it can significantly improve the green energy utilization, and achieve the highest overall revenues for the resource provider.

Shaw SB, Singh AK [15] proposed an approach for VM migration based on forecasting method, in which it first check whether there is a need to migrate the VM or not if a host is found overloaded. The migration of VM depend on present as well as future load, future load is determined by time-series forecasting method, which is a model used to anticipate the future values based on previously observed values. Exponential Smoothing technique is applied to time series data to make forecasts.

If migration occurs, on which PM the VM will be migrate depend on the current as well as anticipated CPU utilization. The number of migration is reduced and energy consumption too while maintaining the SLA.

X. Ruan, H. Chen [16] presented a novel VM allocation algorithm called ”PPRGear” (Performance-to-Power Ratios Gears). They design 11 levels for each type of host and these levels are known as gears(gear 0 to gear10). Gears shows that at which level the host computer is working(from 0%, 10% to 100%). The gear has highest PPR is chosen as the *best gear*. The leading *n* gears with the highest PPRs are chosen as *preferred gears. These calculation of gears made before execution of any task.*

When a host’s working gear is higher than any preferred gears, the host is over utilized. In this case one or multiple VM(s) is/are chosen to migrate out.

When a host’s working gear is lower than any preferred gears, the host is underutilized. In this case the cloud will try to migrate out all VMs then shut the host down. This blueprint is known as PPRGear.

By this approach, optimal balance between host utilization and energy consumption is achieved.

P. Shukla, R.K Pateria[17] proposes an Energy Efficient Dynamic VM Consolidation algorithm for reducing energy consumption based on Inter-quartile Range (IQR) method for finding dynamic threshold. They first find the lower and upper threshold value among the given host utilization. The difference between these two values is known as IQR.

If the host’s utilization is greater than the upper threshold value then this host is considered as overloaded host. In this case load is balanced by selecting appropriate VM to migrate out.

If the host’s utilization is lower than lower threshold value then this host is considered as under-loaded host. In this case all the VM(s) of this host are migrated out to other host by applying server consolidation technique and under-loaded host is switched to idle mode.

The dynamic VM consolidation algorithm finds over loaded host then selects the virtual machine for migration from overloaded hosts and place this VM using VM placement algorithm for Overloaded Host. After load balancing, finds an under loaded host and select all the virtual machines from that host. Place these VMs over least loaded host by using VM placement algorithm for Under loaded Host.

By using this not only the number of VM migrations are minimized but also reduces both energy consumption and SLA violations.

Q. Chen, J.Chen, B. Zheng, J.Cui, Y.Qian [18] presented a utilization-based migration algorithm (UMA) to migrate VMs to stable hosts. A workload detection module is used to classify the hosts as over-loaded, under-loaded and full-loaded.

VM(s) on the over-loaded hosts are computed by using migration probability and selects the VM(s) to migrate out. VM(s) on the under-loaded hosts are consolidated and hence improves the utilization of hosts. Hosts which are full-loaded remain unchanged. By doing so, migration time is reduced and so as power consumption yielding optimal performance of cloud datacenter..

Q. Wu, F. Ishikawa[19] proposed an improved grouping genetic algorithm(IGGA) based on greedy heuristics(Modified Best Fit Decreasing algorithm for VM placement) and swap operation for VM consolidation(reduces the cost of migration). This algorithm concerned with the grouping of objects. A set of VM(s) is partitioned into mutually disjoint subset of PM(s). By this algorithm the best tradeoff between migration cost and power saving is achieved.

M. Gaggero, L.Caviglione[20] proposed an approach for energy-aware consolidation of VM(s) based on prediction of future VM allocations in dynamic model of the cloud. They assume PM(s) are connected through a dedicated local network, VM(s) are re arranged to increase the number of idle PM(s) and PM(s) without any VM(s) can be put into a sleep state. Time require to put a PM into sleep state and wake it up can be considered as negligible because this time is much smaller than the dynamics of the other quantities describing the cloud. At each consolidation run, strategy to migrate VM(s) among PM(s) is computed by solving an optimal control problem over a given prediction horizon.

This approach achieves a tradeoff between violations of the SLA and energy savings.

L.Deng, H.Jin, S. Wu [21] presented an approach in the form of server consolidation manager vMerger. This manager tries to distribute the VM(s) on nodes(PM) to use smaller number of nodes in the presence of fluctuating/ varying workload. This re distribution can be implemented by using topological sorting of VM migration order. Before this redistribution occurs, a prior knowledge of difference between current mapping and new mapping of VM is required, which can be achieved by using Linear programming method. Unnecessary nodes are powered off.

The experimental results show that, vMerger effectively improves the scalability of clusters using server consolidation.

Issam Al-Azzoni[22] proposed a server consolidation approach based on Coloured Petri Nets (CPNs) in heterogeneous clusters. For this approach to work, CPN model is created in which places is used to model the PM(s) and coloured tokens to model the VM(s), and CPN Tools are used to create CPN model. This model captures information of PM(s) on the resources. Some constraints are also incorporated on VM placement directly in model.

Authors in [23] proposed an approach of server consolidation. The allocation problem is considered as a three dimensional(CPU, memory, bandwidth) bin packing problem, which is NP hard. In cloud computing scenario a large-scale problem the algorithm like genetic algorithm exhibits better performance. In this approach First Fit Decrease algorithm is combined with genetic algorithm to solve the bin packing problem, hence it is known as hybrid genetic heuristic algorithm.

This algorithm improves the performance of solving the server consolidation problem.

VI. COMPARISON OF TECHNIQUES SURVEYED

In this section will compare various energy efficient techniques proposed for virtualized datacenter.

Table 1. Comparison of Surveyed Techniques.

Paper	Objective	How much achieved	Compared With	Hardware Considered	Evaluation
[12]	Minimize energy consumption and migrations. Saving hosts.	44.39% & 72.34% of reduction in energy consumption & migration respectively. Saving 34.36% of hosts.	[24] [25] [26]	Bandwidth, Memory of each host.	Cloudsim Simulation
[13]	Minimize energy consumption. Maximize processing capacity.	20% of reduction in energy consumption. 8% increase in capacity.	[27] [28]	4 PC & 4 server processor	Simulation
[14]	Sufficient Utilization of green energy.	Solar energy improves utilization of green energy. High Revenues for resource provider	JOP, DLB, DMVC are compared for objective mentioned.	Virtualized env. of 40 server CPU capacity 1500MIPS	C#.NET Simulation
[15]	Minimize no. of VM migrationsand energy consumption. Minimize SLA violations.	34.59% of reduction in energy . 63.92% of reduction in SLA violations.	Improves the performance of technique describe in [29]	Virtualized env. 800 PM (HP ProLiant ML110 G4/G5) n 1052 VM (with different instances)	Cloudsim Simulation
[16]	Minimize energy consumption.	69.31% of reduction in energy consumption.	[29][30]	800 host computers with 4 different models	Cloudsim Simulation
[17]	Minimize VM migrations.	30% of reduction achieved.	Existing techniques mentioned in [17]	CPU, Memory	Cloudsim Simulation
[18]	Minimize migration time. Minimize power consumption.	77.5%-82.4% of reduction . 39.3%-42.2% of reduction.	[31]	Virtualized env with HP ProLiant ML110 G4/G5 (1860/2660)MIPS	Cloudsim Simulation
[19]	Tradeoff between migration cost and power saving	23.2% power is saved. 29% of reduction in migration cost.	[32] [33] [34] & MBFD	CPU, Memory	Simulation
[20]	Trade-off between SLA violations & Energy saving.	Increase power saving compared with these three. 61% increase in power n 6.6 % reduction in SLA	FDDprod, norm2, & dotproduct Heuristics.	CPU, Memory	MATLAB Simulation
[21]	Maximize scalability of clusters.	Achieved	Serial migration	Node's CPU & Memory	Experiment
[22]	Reduce no. of servers. Minimize migration overhead.	FFD plan is 60% more expensive in terms of migration cost	First Fit Decreasing plan	State space tool's CPU, &Memory.	Simulation
[23]	Increasing the performance of solving server consolidation problem	Achieved	[35]	CPU, Memory	C++ Simulation

VII. CONCLUSIONS:

This survey has discussed energy efficient techniques in cloud computing environment.

To develop sustainable internet-scale IT systems and services, reduction in energy consumption is an important issue considered by any virtualized data center. All the techniques discussed above try to minimize the energy consumption in data center in different ways. Migration time, migration cost, SLA violations, processing capacity, saving hosts, number of VM migrations are some other factors considered while designing.

REFERENCES

[1] Mohsin Nazir, "Cloud Computing: Overview & Current Research Challenges", ISSN: 2278-0661, ISBN: 2278-8727, IOSR Journal of Computer Engineering, Volume 8, Issue 1 (Nov. - Dec. 2012), Pg 14-22.

[2] Dr. Pankaj Pathak, Dr. P.R. Pal, "Cloud Computing – Issues Research and Implementations", ISSN NO.-2321-8088, Internatinal Journal Of Research In Computer Science And Management, Vol. No. 2(2), July 2015, Pg 2-34.

[3] Rajkumar Buyya, Chee Shin Yeo, Srikumar Venugopala, James Broberg, Ivona Brandic, "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility" in ELSEVIER - Future Generation Computer Systems 25 Pg 599-616, 2009.

[4] Yunfa Li, Wanqing Li, Congfeng Jiang, "A Survey of Virtual Machine System: Current Technology and Future Trends" in 2010 Third International Symposium on Electronic Commerce and Security, Pg 332-336.

[5] Sandeep Kaur, Prof. Vaibhav Pandey, "A Survey of Virtual Machine Migration Techniques in Cloud Computing", ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online), Computer Engineering and Intelligent Systems, Vol.6, No.7, 2015.

[6] Divya Kapil, Emmanuel S. Pilli and Ramesh C. Joshi, "Live Virtual Machine Migration Techniques: Survey and Research Challenges" In 2013 3rd IEEE International Advance Computing Conference (IACC), Pg 963-969.

[7] Pankajdeep Kaur,Anita Rani, "Virtual Machine Migration in Cloud Computing", International Journal of Grid Distribution Computing, Vol. 8, No.5, (2015), Pg 337-342.

[8] Bharti Wadhwa, Amandeep Verma, "Energy and Carbon Efficient VM Placement and Migration Technique for Green Cloud Datacenters" In 2014 Seventh IEEE International Conference on Contemporary Computing (IC3), Pg 189-193.

[9] Pragya, Manjeet Gupta, “A Review on Energy Efficient Techniques in Green Cloud Computing”, ISSN: 2277 128X, International Journal of Advanced Research in Computer Science and Software Engineering,Volume 5, Issue 3, March 2015, Pg 550-554.
[10] Perla Ravi Theja, S. K. Khadar Babu, “An Evolutionary Computing based Energy Efficient VM Consolidation Scheme for Optimal Resource Utilization and QoS Assurance”, ISSN (Print) : 0974-6846 ISSN (Online) : 0974-5645, Indian Journal of Science and Technology,Vol 8 (26),October 2015, Pg 1-11.
[11] Tiago C. Ferreto, Marco A.S. Netto, Rodrigo N. Calheiros, César A.F. De Rose, “Server consolidation with migration control for virtualized data centers” in ELSEVIER - Future Generation Computer Systems 27 Pg 1027-1034, 2011.
[12] N.J. Kansal, I. Chana, “Energy-aware Virtual Machine Migration for Cloud Computing - A Firefly Optimization Approach” ,J Grid Computing(2015). Available: DOI: 10.1007/s10723-016-9364-0.
[13] Y. Ding et al.,Energy efficient scheduling of virtual machines in cloud with dealine constraint, Future Generation Computer Systems(2015), Available: http://dx.doi.org/10.1016/j.future.201.02.001
[14] X. Wang et al.,A green-aware virtual machine migration strategy for sustainable datacenter powered by renewable energy, Simulat. Modell. Pract. Theory (2015), Available: http://dx.doi.org/10.1016/j.simpat.2015.01.005.
[15] Shaw SB, Singh AK. Use of proactive and reactive hotspot detection technique to reduce the number of virtual machine migration and energy consumption in cloud data center. Comput Electr Eng (2015), Available: http://dx.doi.org/10.1016/j.compeleceng.2015.07.020.
[16] X. Ruan, H. Chen, “Performance-to-Power Ratio Aware Virtual Machine (VM) Allocation in Energy-Efficient Clouds”. In 2015 IEEE International Conference on Cluster Computing, Available: DOI 10.1109/CLUSTER.2015.46.
[17] P. Shukla, R.K Pateria, “IQR based Approach for Energy Efficient Dynamic VM Consolidation for Green Cloud Data Centers”, International Journal of Computer Applications, Volume 123 – No.9, August 2015 Pg 28-32.
[18] Q. Chen, J.Chen, B. Zheng, J.Cui, Y.Qian , “Utilization-based VM Consolidation Scheme for Power Efficiency in Cloud Data Centers”, In: IEEE ICC 2015 - Workshop on Cloud Computing Systems, Networks, and Applications (CCSNA).
[19] Q. Wu, F. Ishikawa “Heterogenous Virtual Machine Consolidation using an improved grouping genetic algorithm” In: 2015 IEEE 17th International Conference on High Performance Computing and Communications (HPCC), 2015 IEEE 7th International Symposium on Cyberspace Safety and Security (CSS), and 2015 IEEE 12th International Conf on Embedded Software and Systems (ICESS)
[20] M. Gaggero, L.Caviglione “Predictive Control for Energy-Aware Consolidation in Cloud Datacenters” , In IEEE Transactions On Control Systems Technology, Vol. 24, NO. 2, March 2016 Pg 461-474.
[21] L.Deng, H.Jin, S. Wu “vMerger: Server Consolidation in Virtualized Environment” In: 2013 IEEE 11th International Conference on Dependable, Autonomic and Secure Computing.
[22] Issam Al-Azzoni , “Server Consolidation Using Coloured Petri Nets and CPN Tools” 2015 6th International Conference on Information and Communication Systems (ICICS) Pg 32-37 DOI: 10.1109/IACS.2015.7103197
[23] Juan Zha, Chang-Dong Wang, Qui-Liang Chen, Xiao-Yan Lu and Jian-Huang Lai, “Server Consolidation based on Hybrid Genetic Algorithm” In:2015 Ninth International Conference on Frontier of Computer Science and Technology, p num 370-375 DOI:10.1109/FCST.2015.43
[24] Dorigo, M., Gambardella, L.M.: Ant colonies for the traveling salesman problem. BioSystems 43, 73–81 (1997)
[25] Ludwig, S.A., Moallem, A.: Swarm intelligence approaches for grid load balancing. J. Grid Comput. 9(3), 279–301 (2011)
[26] Yue, M.: A simple proof of the inequality FFD(L ≤(11/9)OPT(L) + 1, for all L, for the FFD bin-packing algorithm. Acta Math. Appl. Sin. 7(4), 321–331 (1991)
[27] G. Laszewski, L. Wang, A.J. Younge, X. He, Power-aware scheduling of virtual machines in DVFS-enabled clusters, in: IEEE International Conference on Cluster Computing and Workshops, 2009, Pg 1–10.
[28] A. Beloglazov, J. Abawajy, R. Buyya, Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing, Future Generation Computer System 28 (5) (2012) Pg 755–768.
[29] Beloglazov Anton, Buyya Rajkumar. Optimal online deterministic algorithms and adaptive heuristics for energy and performance efficient dynamic consolidation of virtual machines in Cloud Data Centers. Concurr Comput: Pract Exper 2012:1397–420. Wiley InterScience.
[30] Tom Gurout, Thierry Monteil, Georges Da Costa, Rodrigo Neves Calheiros, Rajkumar Buyya, and Mihai Alexandru. Energy-aware simulation with {DVFS}. Simulation Modelling Practice and Theory, 39(0):76 – 91, 2013. S.I.Energy efficiency in grids and clouds.
[31] A. Beloglazov , R. Buyya, "Optimal Online detenninistic algorithms and adaptive heuristics for energy and performance efficient dynamic consolidation of virtual machines in cloud data centers", concurrency and computation: practice and experience (CCPE). vo1.24, no.13, 2011.
[32] G.Dasgupta, A.Sharma, A.Verma, A.Neogi, R.Kothari, “Workload mamgement for power efficiency in virtualized data centers”, Communication of the ACM, Vol 54, Pg 131-141,2011.
[33] A.Verma, P.Ahuja, A.Neogi, “pMapper: Power an Migration Cost Aare Application Placement in Virtualized Systems”, In Midddleare 2008, Vol 5346: Springer, 2008, Pg 242-264.
[34] X.-F. Liu, Z.-H. Zhan, K.-J. Du, W.-N. Chen, “Energy aware virtual machine placement scheduling in cloud computing based on ant colony optimization approach”, In Proceedings of 2014 Conference on Genetic and evolutionary computations, 2014, Pg 41-48.
[35] G. D´osa, “The tight bound of first fit decreasing bin-packing algorithmis ffd (i) 11/9opt (i)+ 6/9,” in Combinatorics, Algorithms, Probabilistic and Experimental Methodologies. Springer, 2007, Pg 1–11.