Energy Efficient Green Cloud Data Centres using Dynamic Virtual Machine Placement: A Survey

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Abstract *-Cloud Computing is considered as an promising technology in which massive amount of resources such as applications, network, computer host, storage and database are assembled in large data centres. They are interconnected through common internet protocols by means of reliable, economical and safe manner to a large number of users of the geographically dispersed area. But these massive-scale data centres are energy hungry data centres which are consuming large amount of energy day by day. It is also a threatening to the environment by emitting increased amount of Carbon dioxide. Hence, an efficient management for energy conservation is arising as a necessity in the cloud environment. An effective way to advance the energy efficiency of such data centers by using Server Consolidation which tries to lessen the sum total of active Physical Machines within a data center. An extensively practiced technology for VM live migration and placement perform as a key for finest consolidation of resources dynamically. This paper proposes a comprehensive study of the dynamic VM placement and its consolidation techniques used in green cloud computing which has the aim for improving the energy efficiency.*

Keywords *-Cloud Computing, Green Cloud Computing, Data Center, Virtual Machine Placement, Virtual Machine Live Migration*

I. INTRODUCTION

Cloud Computing is an emerging and promising paradigm in the present world. It is a technology which provides computing resources as a utility like electricity on a metered basis which allows running the workloads similar to grid computing [1]. It delivers its resources such as software, storage, network and databases in reliable, inexpensive and secure means to a large set of users through common internet protocols. These resources are concentrated in large energy greedy data centres.

The amount of energy consumption of data centers is doubling-up in every five years. In 2014, U.S. data centers devoured around 70 billion KWh, that in lieu of approximately 2% of aggregate electricity consumption of U.S.A. Based on recent trend, U.S. data centers are estimated to expend around 73 billion KWh in the upcoming year 2020 [2]. Each datacenter is emitting 170 million metric tons of carbon dioxide per year. The anticipated global carbon emissions by data centers in 2020 will be 670 million metric tons per annum. Presently, data centers devour up to 3% of all worldwide power generation while delivering 200 million metric tons of carbon dioxide.
Studies shows that the average consumption of data centers can be nearly 25% and energy utilized by the idle resource is can be as regard as 70% of its own peak power. Low Return on the Investment (ROI), system devour up to 3% of all worldwide power generation while delivering 200 million metric tons of carbon dioxide. Studies shows that the average consumption precariousness, as well as much more Carbon dioxide emissions can be created because of this sky-scraping energy burning up of data centers.

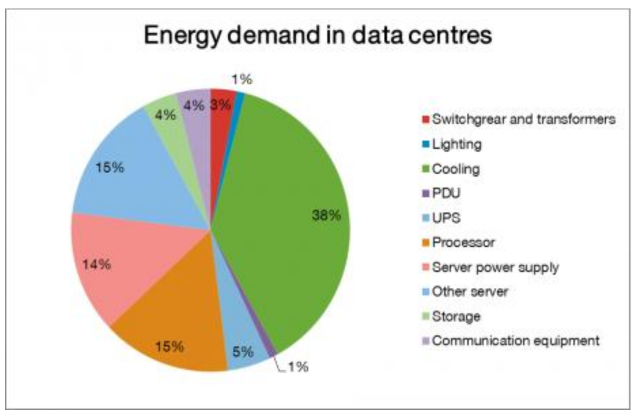

Fig1:Data Center energy consumption

II. GREEN CLOUD COMPUTING

As rapid growing up of data and applications in the computing world needs the increased amount of huge servers along with disks are necessary to forward them quickly inside the required time span. Hence, the minimization of the energy consumption of data centers is a challenging and intricate subject recently. Green Cloud computing is a new paradigm which foreseen to attain not only efficient processing with optimum utilization of computing resources, but also cut down energy consumption. This is vital for guaranteeing that the future development of Cloud Computing is prolonging. To deal this issue, the resources of data centers are required to be handled in an energy efficient way to implement Green Cloud Computing. Before all else, cloud resources are assigned not only to minimize energy usage, but also assure QoS necessaries demanded by naive users via Service Level Agreements (SLA) [3].

Green Computing is the strong movement towards a more environmentally prolonged computing or IT, via various studies, practice and observation of proficient and eco-friendly computing concepts. Green computing is required to minimize the power consumption and environmental pollution [4]. The strategies required to access green computing are Virtualization, Cloud computing, Green Data Center and Energy optimization. Green Cloud Computing (GCC) is the grand total of green computing and cloud computing. The main purpose of GCC to improve the energy efficiency and minimize the power usage and use of hazardous as well as toxic materials. GCC is the art of designing, manufacturing, using as well as disposing of servers and other peripheral devices like monitors, printers, storage devices etc., effectively and efficiently to reduce the power consumption which will lead to a safe environment.

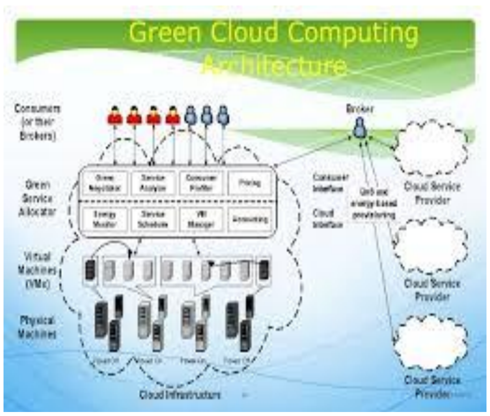

Fig 2: Architecture of Green Cloud Computing

Fig 2 illustrates the high-level structural design for implementing energy efficient service allotment in Green Cloud computing infrastructure. This is mainly four main units are involved:

I. Consumers: Cloud consumers or behalf of them their intermediaries can be submitted service demands from anyplace in the globe to the Cloud. This is significant to observe that there can be a distinction among Cloud consumers with users of these organized services. For instance, a consumer can be a “company” providing a Web application”, which shows differentiating in order to access the services by users”.

II. Green Resource Allocator: It operates as the integrator among the Cloud infrastructure with consumers. It entails to the interaction of the following parameters to carry for the energy efficient resource administration:

• Green Negotiator: It consults with the consumers/ intermediaries to settle the SLA with specific costs and penalties (for infringement of SLA) between the Cloud supplier and consumer rely on the consumer’s QoS prerequisites and energy sparing systems. In the event of Web applications, for instance, QoS metric can be 95% of requirements being prepared in less than 3 seconds.

• Service Analyzer: Before deciding whether to admit or decline the submitted requirements, Service Analyzer interprets and investigates the service necessities of it. Subsequently, it needs the current load from VM Manager and energy data from Energy Monitor.

• Consumer Profiler: Collects definite practices of consumers with the goal chief consumers can be awarded individual privileges and priorities above other consumers.

• Pricing: It comes to a decisions to how service requirements are priced to handle the supply and demand of computing assets and assist in assigning priorities in service allocations effectively.

• Energy Monitor: It monitors and verifies which physical machine to switch on/off.

• Service Scheduler: It allocates requirements to VMs and verifies resource privileges for assigned VMs. It too fixes on when and where VMs are to be inserted or eliminated to meet up the demand.

• VM Manager: It keeps up the method for the user-friendliness of VMs and their own resource rights.It is also in obligation of migration of VMs widely different physical machines.

• Accounting: Keeps the real resource consumption by demands to calculate consumption prices. Historical consumption information can also be utilized to develop the assessments of service allocation.

III. Virtual Machines: Several VMs can be started and stopped with dynamism on a solitary physical machine to acquire assigned requests, thus implementing maximum elasticity to construct different divisions of resources on the similar PM to unique service requests explicit requirements. Numerous VMs are in parallel for running applications in context of diverse OS platforms on a solitary PM. Moreover, by dynamic migration of VMs across PMs, workloads can be united and unutilized resources can be put on a minimum-power state, switched off or build up to work at minimum performance points (e.g., by using DVFS) so as to save power consumption.

IV. Physical Machines: The fundamental physical servers offer hardware infrastructures for building virtualized resources to convene service requests.

III. VIRTUALIZATION

Virtualization is a key technology which acts as a powerful tool that improves power efficiency of data centers by enabling to allow the multiple virtual machines (VMs) to share the physical resources of a single server. A virtual machine (VM) is an instance of an operating system (OS) or an application environment that is installed as software, which acts like a dedicated hardware. The end user has the same experience on a virtual machine as they would have been on an actual machine. Every VM has its own features and consumption of unique amount of energy depending upon the usage of resources and thus emit different quantities of carbon footprint. The total carbon footprint of the data center is proportional to the energy usage by each host[5]. The configuration of the multiple VMs on the same physical machine helps in consolidating the task and turning off other physical machines which will helps to cut down the energy consumption level to a great extend.

The virtualization technology initiates software abstraction layer which is known as Virtual Machine Monitor (VMM) or hypervisor. Mainly, two virtualization architectures are using [6]. They are:

- ✓ **The Hosted architecture**: The virtualization layer is configured as an application on top of OS and it maintains bulky collection of hardware.
- ✓ **The Hypervisor (bare-metal) architecture:** The virtualization layer is installed straightly on x86 standard hardware.

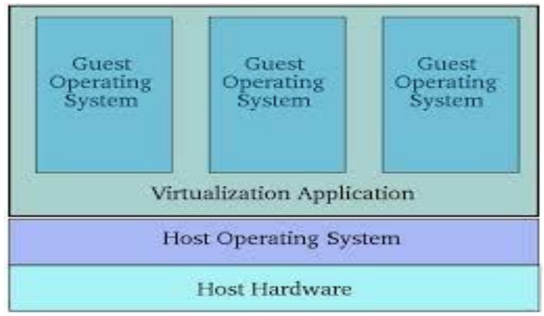

Fig 3: Virtualization diagram

A. Types of Virtualization

➢ **Hardware/Server Virtualization**

The basic idea of the technology is to merge many small physical servers into one large physical server, so that the processor can be used more effectively and efficiently. It is further divided into three [7]:

- ✓ **Full Virtualization:** All OSs in full virtualization converse in direct with the VM hypervisor, so guest OSs do not need for any alteration. Guest OS in full virtualization structures are usually quicker than other virtualization designs.
- ✓ **Para Virtualization:** Para virtualization requires that the host OS provides a VM interface for the guest OS and that the OS procure hardware via that host VM. An OS executing as a guest on a para virtualization system which must be ported to work with the host interface.
- ✓ **Emulation:** The VM imitates as hardware. So it might be independent of the fundamental hardware system. A guest OS which is to be used emulation does not require to be updated in any manner.

➢ **Network Virtualization**

It refers to the organization and monitoring of a computer network as a single managerial unit from single software based administrator's console. It is planned to permit network optimization of data transfer rates, flexibility, reliability, scalability and security.

- **Storage Virtualization**

  In this virtualization, various network storage resources are viewed as a single storage device for easier and more resourceful management of these resources. There are mainly two types of storage virtualization:

  - ✓ **Block-**It acts prior to the file system exist. It restores controllers and takes over at the disk level.
  - ✓ **File-** The server that makes use of the storage must have software installed on it so as to enable file-level usage.

- **Memory Virtualization**

  It initiates a way to decouple memory from the server to offer a shared, distributed or networked function. It improves performance by providing large memory capacity without any main memory addition.

- **Software Virtualization**

  It offers the ability to the main computer to run and produce one or more virtual environments. It is used to enable a complete computer system so as to permit a guest OS to run. Types of software virtualization:

  - ✓ Operating system
  - ✓ Application virtualization
  - ✓ Service virtualization

- **Data Virtualization**

  Exclusion of any technical features, user can easily manipulate data and knowledge, it is set-up or where it is physically located. It reduces the data errors and workload.

- **Desktop virtualization**

  It offers the work handiness and security. As one can access remotely, user is able to work from any location and form on any PC.

IV. VIRTUAL MACHINE MIGRATION

Virtual Machine Migration is important feature of virtualization for efficient handling of resources. The VM migration technique helps to move virtual machines from one physical machine to another without the suspension of the VM. Migration is the potential tool for the load balancing, server consolidation (cold spot migration) as well as overloaded migration (hot spot migration).Server consolidation is the situation where the load on the host is below the lower threshold i.e., the server is considered as underloaded, and overloaded migration is the situation where the current host in which virtual machine is running is not able to satisfy the requirement of the VM because of its load is above the upper threshold value.VMMigration could be done by using different algorithm like first fit, best fit, worst fit, monte carlo, round robin etc. [8].

A. Techniques of Virtual Machine Migration

There are two types of migration. They are:

- **Live Migration:** Live migration is the most salient feature of the Virtualization. It is facilitating the cloud provider to balance the system though the migration. It helps to assign a VM to one physical host of another without the suspension of any of its work and it seems to be as previous state without any obvious outcome from the end user's point of view. The Live migration and the SLA administration dealing with the following challenges in dynamic VM consolidation[9]:

  - ❖ Determination of the overloaded PM.
  - ❖ Determination of the underloaded PM.
  - ❖ Selection of the VM for migration.
  - ❖ Placement of the selected VM.

- **Regular Migration:** Regular or Cold migration is the migration of a switched-off virtual machine. With this migration, user has option of moving the related disks from one data location to another. The VMs are not needed to be on a shared storage.

V. VM PLACEMENT

The placement of VMs among PMs is treated as a bin packing problem[10]. Some popular solutions of this problem are:

- **The First Fit (FF)**: First Fit begins with the most lively bin and tries to pack every item in it before going into next bin. If appropriate bin is not to be found for the item, then the subsequent bin is elected to locate as the new bin.

- **First Fit Decreasing (FFD)**: In FFD the items are arranged in descending order and after that items are processed as in the method of using First Fit algorithm.

- **Best Fit Decreasing (BFD)**: Like FFD, BFD also arranges items in descendingorder and afterwards for packing items it prefers a bin with minimum vacant space to be left there after the item is being packed.

- **Worst Fit Decreasing (WFD)**: Worst Fit Decreasing works accurately equal to BFD apart from in one thing, rather than selecting bin with least empty space it opts bin with greatest empty space to be left ther after the allotment of item on that bin.

- **Second Worst Fit Decreasing (SWFD)**: Commensurate WFD, it just select bin with second least empty space. It is also called as Almost Worst Fit Decreasing (AWFD).

VI. VM ALLOCATION POLICIES

At the point when a host is hailed as being over utilized, this implies the VM is as of presently utilizing more MIPS than areas of presently accessible on that host or that it is above the threshold value set by the individual allocation policies. Some of VM allocation policies are:

- **Median Absolute Deviation(MAD)** –MAD is a powerful measurement which measures the changeability of a set o of facts. This is like a standard deviation however is measured to be a more tough measurement as it is less delicate to exceptions in a data index. This is because of the way that standard deviation utilizes a squared mean which can significantly change the variation if the information point is significantly adequate. For MAD, a vast deviation or even a couple of extensive deviations have no impact on the median.

- **Interquartile Range(IQR) - IQR** is a measurement for unevenness, in light of isolating a data set into quartiles. Quartiles partition a position-oriented data set into four equivalent parts. The values that split each element are known as the primary, secondary, and third quartiles; then they are denoted by Q1, Q2 and Q3, correspondingly. The IQR is a symmetric distribution because of its connection to the MAD.

$$0.5*IQR = MedianAbsoluteDeviation$$

- **Local Regression(LR)** - LR technique is depends on the LOESS local regression algorithm. This algorithm takes a restricted set of the data and endeavors to discover the deviation in the data from point to point. This is done by utilizing locally weighted polynomial regression methods. While utilizing the weighted least squares technique, the data points that are nearer to the approximate to get weighted greater than the data points that are auxiliary from the approximation.

- **Robust Local Regression(RLR)** - RL is as stated to be robust when its algorithm is not sensitive to an off base presumptions. By means of the similar LOESS regression algorithm as the local regression data set, but changing the system to which the values are weighted enables this regression algorithm to be viewed robust. This implies that the algorithm could be deaden to an outlying model which might be conciliation the strength of a standard regression algorithm.

VII. VM SELECTION POLICIES

Formerly a PM has been decided as overutilized by the VM allocation policy, the choice strategies will figure out which VM's will be migrated from the aforementioned PM to bring the PM back to a more competent rank.

- **Minimum Migration Time (MMT)** – This elementary selection strategy analyze the amount of RAM consumed by each and every VM inside a PM. The bigger the VM, the higher data there will be to shift, so the littlest VM in the RAM of the PM will be the excellent to migrate.

- **Random Selection (RS)** – The RS technique accesses the number of VMs within a PM and forms a random digit generated starting from 0 to that range. It applies the index coupled with each VM in a PM to establish which VM has that allocated digit.

- **Minimum Utilization (MU)** – The MU policy brings out the list of VMs within an overutilized PM and locates the VM with the lowest MIPS requisites for that timespan and forwards it in to migration process.

- **Maximum Correlation (MC)** – The utmost utilization brings out a list of migratable VMs from a PM that has been decided to be overutilized. This list is applied to construct a migration grid in accordance with the volume of the list and the least amount consumption of the list. The correlation coefficient is established by taking the transpose of the migration grid so that it is becoming a linear model and afterward it utilizing linear regression. The LR technique is utilized as the similar linear regression technique for the linear regression allocation policy. While assessing the correlation coefficients of the VMs, the VM among the uppermost coefficient is the VM to be migrated.

VIII. RELATED WORK

Currently, several efficient researches are conducting in the area of improving energy efficiency though proper utilization of resources in cloud data centres. It will helps to reduce the green house gas such as CO_2 emission and made an eco friendly IT structure. In this section, we review significant tackles suggested in the literature for attaining energy efficiency in cloud data centers. In the region of cloud computing, power management policies and Virtual Machine consolidation through VM migration and VM allocation techniques are playing the key role of achieving energy efficiency.

Dario Bruneo et al. [11] invited our attention of the study on the cost- benefit of several virtual resource allocation policies in connection with the green IaaS cloud by using an analytical framework which is derived from stochastic reward nets for energy saving context for both from user and provider perspective.

Zhe Huang et al. [12] proposed VM consolidation framework named M-convex optimization framework for an automated VM consolidation process for assigning VMs and Servers with minimum system reconfiguration. Through this approach performance efficiency of data centres is achieved and scalability is improved.

Fahimeh Farahnakian et al. [13] have analyzed VM consolidation based on a meta heuristic algorithm called Ant Colony System which makes an effective use of artificial ants to consolidate VMs into a reduced number of PMs as per the workload and these ants are doing their own work in parallel to establish VM migration.

Michael Pantazoglou et al. [14] have proposed for managing the workload of VM objects are provided by large enterprise clouds by a fully de-centralized manner in scalable and energy-efficient method. In this approach, the resources of the data center are efficiently organized into a hypercube structure via applying a set of distributed load balancing algorithms.

Fahimeh Farahnakian et al.[15] have investigated Utilization Prediction aware VM Consolidation (UP-VMC) - a Dynamic VM consolidation approach which creates a VM consolidation as a way of multi-objective vector been packing problem. By the advent of a regression-based prediction model which is exercised for the prediction of current as well as prospect resource utilization by consolidating the VMs into the decreased number of active PMs. VM selection consider MMT (minimum migration time) strategy and VM allocation consider Modified Power Aware Best Fit Decreasing with SLA factor.

Quanwang Wu et al.[16], have presented the clarification for bi-objective optimization problem which will help to limit the cost of VM migration to save energy by means of dynamic VM consolidation in a heterogeneous cloud datacenter where large number of physical machines.

J. Octavio Gutierrez-Garcia et al. [17] in an efforthave investigated distributed problem solving procedures for data centers' load management via live migration of VM. Collaborative Agents are provisioned with when, which and here the Virtual Machines to be migrated and decide the policies for selecting the time to power on/off the Physical hosts.

Youwei Ding et al. [18] have analyzed the virtualization technology which is the key strategy for the energy efficiency in cloud data centres. In their work they devised another VM scheduling algorithmcalled EEVS which facilitates tocut-down the total energy usage by the cloud which supports DVFS also. The PM with bestpower performance ratio will be assigned to process the VMs primarily to save power.

Kim Khoa Nguyen et al.[19] investigated an environment-conscious model for virtual slices that enabled the progressing of energy efficiency in handling with recurrent renewable energy sources. A virtual slice dwells of excellent streams allocated to VMs in a virtual data center based on traffic needs, locations of VMs, physical network facility and availability of renewable energy.

Mehiar Dabbagh et al. [20] have been proposed an amalgamated energy-efficient, forecast-oriented VM placement and migration framework for resource allotment. They proved that the framework declines the performance deprivation due to overloads of host by reducing the number of PMs which resulted a significant reduction of energy consumption.

Table 1. Comparative Analysis

Author	Scheme	Methodology	Achievements	Future works
M.A.Khoshkholgh i et.al. [21]	Dynamic consolidation of Virtual Machines	The proposed dynamic VM consolidation Mechanism (PCM) Algorithm	i) Minimizing the energy usage of a data center ii) Assurance needed system performance under SLA constraints concerning about CPU, RAM, and BW	i) Implementation of a strong network topology for VM communication while implementing VM consolidation ii)Performance-aware strategy for various workloads of heterogeneous servers
Jungmin Son et al. [22]	Dynamic overbooking strategy by joining virtualization SDN for VM and traffic consolidation	Dynamic Overbooking algorithm	i) Saves energy consumption in the data center ii) Reducing SLA violations	i) Prediction component for correlation analysis to predict both VM utilization and data rates of flows for the next time slots. ii)Extend the algorithm to heterogeneous data centres
Xiao-Fang Liu [23]	Evolutionary computing is pertained with VM Placement to reduce the number of active physical servers while switching off the under utilized servers	Order Exchange and Migration Ant Colony System-OEMACS-algorithm	i) Notable savings of energy ii) Extensive use of different resources	Plan to extend the work in real cloud environment
Amany Abdelsamea et al.[24]	VM consolidation enhancement through CPU, memory and bandwidth utilization factors	Multiple Regression Host Overload Detection – MRHOD algorithm	i) Reduces power consumption ii) Improves ESV metrics	Plan to extend the hybrid idea to various management chores of cloud controllers
Yang Yang et.al [25]	Designing a Virtual Data Centre which manages with Physical resource allotment in virtual nodes.	Green Best-First Search Nearest-edge-Switch Servers (NSS-GBFS)and NSS.JointSL algorithm	NSS-JointSL and NSS-GBFS, to address VDCE issue with the objective of diminishing the energy consumption in light-workload CDCs while limiting the embedding cost in bulky-workload CDCs.	To design parallel algorithms to reduce the computation time.

IX. CONCLUSION

Cloud Computing is deemed as an emerging paradigm in which large set of resources such as applications, network, computer host, storage and database are accumulated in huge data centres. They are interconnected through common internet protocols by way of reliable, economical and safe manner to a large number of users of the geographically dispersed area. But due to increased data in present time, these data centres are consuming excessive power which adversely affects the environment by emitting huge amount of CO_2. Several researches are recently conducting on the basis of the service reliability with energy efficiency. So the Green Cloud Computing with novel technologies like virtualization , server consolidation, resource allocation and resources utilization are used to save a considerable amount of energy which reduce the CO_2 footprint.Virtual machine migration occupies an significant position in cloud computing for the better use of resource while reduction of energy conservation. But VM migration is a chief issue in cloud computing. With the increase in the acceptability of cloud computing environment, VM migrations across data centers and dissimilar resource pools will be greatly helpful to data center administrators. In this paper we observed about the cloud computing, virtualization, types of virtualization, virtual machine migration and its various techniques to achieve Green Cloud Computing environment. Subsequent extensive investigation of VM Consolidation for the cloud datacenters we review many strategies for overload/Under load detection of PMs, VM selection , VM placement and VM Migration. In this exploration, we reached a conclusion that Multiple Regression Host Overload Detection algorithm [24] for host overload detection, is a superior judgment for VM selection for live migration and energy aware best fit decreasing for VM placement to achieve a better result by getting the highest user satisfaction without increasing consumption of power.

As a future enrichment, we can propose a new innovation, which diminishes the trade-off among power utilization and better QoS performance. There can be an agenda by making use of a hybrid approach which treats a blend of server consolidation for accessing energy-efficiency plus it executes load balancing techniques to convey superior quality of service to the ultimate users. These techniques collectively consecutive a greeny data centre that will provide an eco friendly environment which is a necessity for present world.

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REFERENCES

[1] P. Mell and T. Grance, *The NIST definition of CloudComputing*,http://csrc.nist.gov/publications/PubsSPs.html #800- 145, September 2011, (Accessed September, 2017)

[2] A. Beloglazov, J. Abawajy and R. Buyya, "*Energy-aware Resource Allocation Heuristics for Efficient Management of Data Centres for Cloud Computing*", Future Generation Computer Systems, vol. 28, no. 5, pp. 755–768, October 2012.

[3] *"Limiting Global Climate Change to 2 degrees Celsius – The way ahead for 2020 and beyond"*, publications.europa.eu/ resource/ uriserv/l28188.ENG

[4] S.Murugesan, "*Harnessing green IT: Principles and practices.*"IT professional, Vol.10.No.1, IEEE pp:24-33 ,2008.

[5] R.Buyya "*Cloud Computing: Principles and Paradigms*", Vol. 87, John Wiley & Sons, 2010. ISBN: 978-0-470-88799-8

[6] S. S Raza, A.H. Jaikar, and S.Y Noh. "A performance analysis of precopy, postcopy and hybrid live VM migration algorithms in scientific cloud computing environment." In *High Performance Computing & Simulation (HPCS), 2015 International Conference on*, pp. 229-236. IEEE, 2015.

[7] S. Suehring. *" Cloud Computing Bible* " Wiley Publishing." 2007.

[8] A.Beloglazov and R.Buyya, "*Managing Overloaded Hosts for Dynamic Consolidation of Virtual Machines in Cloud Data Centers under Quality of Service Constraints*," IEEE Transactions On Parallel And Distributed Systems, Vol. 24, No. 7, July 2014.

[9] V. Malik and C. R. Barde, "*Live migration of Virtual Machines in Cloud Environment using Prediction of CPU Usage*", International Journal of Computer Applications, 2015.

[10] Y.Han, J. Chan, T.Alpcan, and C. Leckie, "*Using Virtual Machine Allocation Policies to Defend against Co-resident Attacks in Cloud Computing*", IEEE Transactions On Dependable And Secure Computing, 2015.

[11] D.Burneo,A.Lhoas, F. Longo and A.Pulicito, "*Modelling and Evaluation of Energy Policies Green Clouds*", IEEE Transactiobs on Parallel And Distributed Systems, Vol.26,No.11, 2015.

[12] Z.Huang and D. H.K. Tsang, "*M-convex VM Consolidation: Towards a Better VM Workload Consolidation*", IEEE Transactions on Cloud Computing, Volume: 4, Issue: 4, 2016

[13] F. Farahnakian, A.Ashraf, T. Pahikkala,P. Liljeberg, J. Plosila, I. Porres andH.Tenhunen, "*Using Ant Colony System to Consolidate VMs for Green Cloud Computing"*, IEEE Transactions On Services Computing, Vol. 8, No. 2, 2015.

[14] M. Pantazoglou, G.lTzortzakis and A.Delis, "*Decentralized and Energy- Efficient Workload Management in Enterprise Clouds*",IEEE Transactions On Cloud Computing,Volume:4, Issue: 2, 2016.

[15] F. Farahnakian, T. Pahikkala, P.Liljeberg,J.Plosila, N.TrungHieu, and H.Tenhunen, "*Energy-aware VM Consolidation in Cloud Data Centers Using Utilization Prediction Model"*, IEEE Transactions on Cloud Computing Volume: PP, Issue: 99 , 2016.

[16] Q. Wu, F. Ishikawa, Q. Zhu and Y. Xia, "*Energy and migration cost-aware dynamic virtual machine consolidation in heterogeneous cloud datacenters*", IEEE Transactions on Services Computing, Volume: PP, Issue: 99 , 2016.

[17] J. Octavio G.Garcia and A.R.Nafarrate, "*Collaborative Agents for Distributed Load Management in Cloud Data Centers using Live Migration of Virtual Machines*",IEEE Transactions on Services Computing , Volume: 8, Issue: 6, 2015.

[18] Y.Ding, X.Qin, LiangLiu and T.Wang "*Energy efficient .scheduling of virtual machines in cloud with deadline constraint*",Future Generation Computer Systems, Elsevier Volume 50, Issue C, Pages 62-74 2015.

[19] K. K. Nguyen and M. Cheriet, "*Environment-aware Virtual Slice Provisioning in Green Cloud Environment*", IEEE Transactions on Services Computing, Volume: 8, Issue: 3, 2015.

[20] M.Dabbagh, B.Hamdaoui, M. Guizani and A.rRayes, "*An Energy-Efficient VM Prediction and Migration Framework for Overcommitted Clouds*", IEEE Transactions on Cloud Computing Volume: 7, Issue: 4, 2017.

[21] M. A. Khoshkholghi, M. N.Derahman, A.Abdullah, S.Subramaniam and M. Othman, "*Energy- Efficient Algorithms for Dynamic Virtual Machine Consolidation in Cloud Data Centers*", EEE Transactions on Green Cloud and Fog Computing: Energy Efficient and Sustainable

Infrastructures, Protocols and Applications Vol. 5 , Issue: 69 PP no: 10709 – 10722, 2017.

[22] Jungmin .Son, A. V. Dastjerdi, R. N. Calheiros and R. Buyya , "*SLA-aware and Energy-Efficient Dynamic Overbooking in SDN-based Cloud Data Centers*" ,IEEE Transactions on Sustainable Computing Volume: 2, Issue: 2, 2017.

[23] X.F. Liu, Z.H. Zhan, J. D. Deng, Y. Li, T. Gu and J.Zhang, "*An Energy Efficient Ant Colony System for Virtual Machine Placement in Cloud Computing*", IEEE Transactions on Evolutionary Computation Volume: PP, Issue: 99 PP no: 1 – 1, 2016.

[24] A.Abdelsamea, A. A.El-Moursy, E. E.Hemayed, and H.Eldeeb, "*Virtual machine consolidation enhancement using hybrid regression algorithms*", Egyptian Informatics Journal, ScienceDirect, Volume: 89 Pages: 27-33 ,2017.
.

[25] Y. Yang, X.Chang, J.Liu and L. Li, "*Towards Robust Green Virtual Cloud Data Center Provisioning*",IEEE Transactions on Cloud Computing, Volume: PP, Issue: 99, 2017.