Network-Aware Dynamic VM Placement for Achieving Energy Efficient Greeny Data Centres: A Review

Sajitha.A.V.*, Dr.A.C.Subhajini**

*Research Scholar, Department of Computer Applications, Noorul Islam Centre for Higher Education, Noorul Islam University,
**Assistant Professor,Department of Computer Applications, Noorul Islam Centre for Higher Education, Noorul Islam University, Tamil Nadu, India

Abstract-Today's Cloud data centers consist of thousands of physical machines (PMs)including large number of computing, storage devices and network resources for the cloud applications are hosted in numerous networked Virtual Machines which are subjugated by complex applications including numerous computing and data modules with solid correspondence correlations between them. Out of these resources, network resources uphold adding complexity and claim for scalability and elasticity. Thus Virtual Machine Placement (VMP) demands a critical discussion in present scenario. Hence, proper VM placement helps to achieve energy efficiency via reduce the CO_2 emission to ensure a green computing environment for eco friendly. This paper evaluates the literature on network-aware Dynamic VM placement in cloud data centers.

Index Terms: Cloud Computing, Cloud Data Center ,Green Cloud Computing, Network-aware Virtual Machine Placement, Virtual Machine Live Migration

I. INTRODUCTION

Cloud computing is an emerging and promising standard in recent years. It is gaining its popularity among organizations that wish to eliminate the strain of managing their own IT infrastructure via outsourcing the computational resources. It is a technology which provides computing resources as a utility like electricity on a metered basis that permits the operations of the workloads similar to grid computing [1]. It distributes its resources, for instance, software, storage, databases and network in consistent, economical and safe manner to a large number of users via accepted internet protocols and these resources are accumulated in geographically dispersed energy hungry data centers.

To facilitate the optimization of the overall quality of cloud services, multiple objectives could be measured, such as: work load balancing, resource utilization maximization, energy consumption minimization, etc. Over the years, several research started to investigate the networking component as one of the significant factors that impact the behavior of cloud data centers.

The quantity of energy consumption of data centers is cloning for every four years. In 2016, the worldwide data centres were used the 416.2 terawatt hours of electrical energy was considerably exceeding the UK's total power consumption of around 300 terawatt hours [2]. It is inviting not only as a burden such as huge cost to the service provider, but also has an environmental brunt. The more amount of energy consumption means that more amount of the CO_2 emission. It is calculated in terms of Carbon footprints. Forthwith, the data centers deplete up to 3% of all worldwide electricity production, while emitting 200 million metric tons of Carbon Dioxide. The estimated global Carbon emissions by data centers in 2020 will be 670 million metric tons by the year.

II. GREEN CLOUD COMPUTING

As the speedy development of data and applications in the cyber world demands the excessive number of gigantic servers and disks are required to process them quickly within the fixed time span. Therefore, the decrease in the energy consumption of data centers is a sticky wicket recently. Green cloud is a buzzword that forecast to attain not only the competent processing along with utilization of computing resources but also lessen the energy consumption. It refers promising ecological prosperities that Information Technology (IT) services delivered over the Internet can propose to the general public. The concept unites the two terms – green computing, means strong revolution towards a more environmentally extended computing or IT, via diverse studies, practices and observations of skillful and eco-friendly computing concepts -- and cloud computing, mentions the ultimate sign for the cyberspace and the precise title for a kind of on demand self service delivery model. Furthermore, cloud resources are allocated not only to diminish energy usage, but also reassure QoS necessities required by users by means of Service Level Agreements (SLA) [3,4].

III. NETWORK TRAFFIC IN CLOUD DATA CENTRES

Cloud suppliers are conveying vast-scale datacenters containing thousands of servers all over the world, with regard to meet the quickly growing requirements for computing, networking, as well as storage resources. These data centers are enduring a sudden big ascend in network traffic. A good deal of this traffic is composed because of the data communiqué inside the data center. The study predicts by Cisco(2016) that universal data center traffic will nearly triple from 2016 to 2021 with a combined annual growth rate (CAGR) of 24% growing from 3.6 zettabytes/year by 2021. A zettabyte is trillion gigabytes. Per month IP traffic will attain 35 GB per capita by the year 2021, up from 13 GB per capita in the year 2016[5]. The Cloud data centers will monopolize the global data center traffic stream for the anticipated future and its significance is featured by one of the top line projections from the above mentioned estimate, by 2021, in excess of three-fourths of the entire data center traffic will generated from Cloud traffic (Fig 1) which is the outcome of data communication within the data centers.

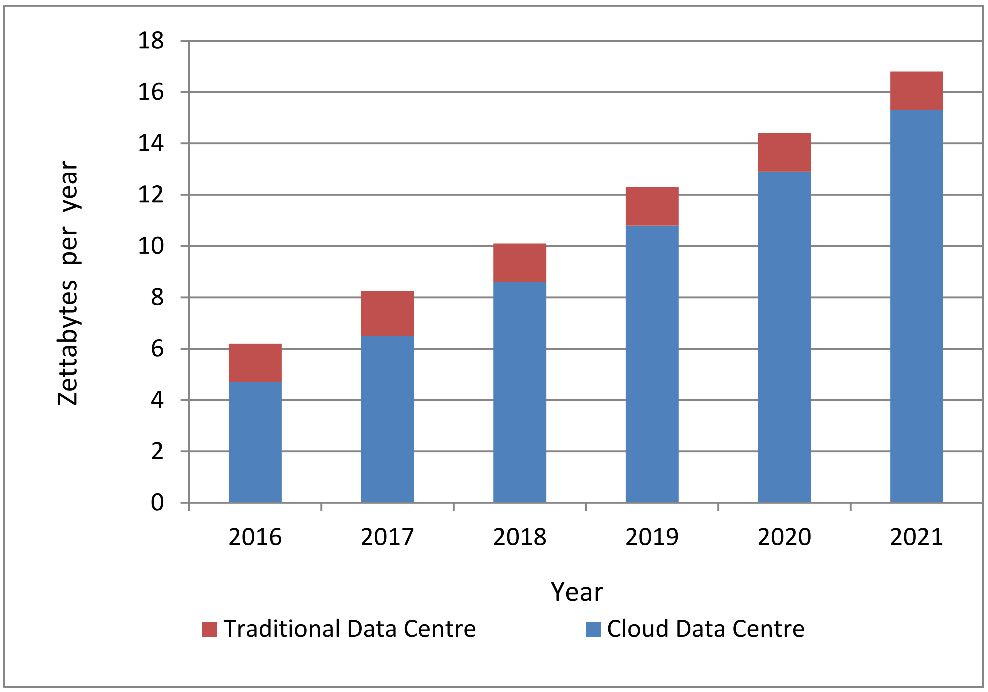

Fig 1: Global Data Center Traffic growth (data source: Cisco).

IV. VIRTUALIZATION

Virtualization is one of the key advancements in cloud computing which acts as a dominant tool. The IaaS service model maintains resource multiplexing via virtualization innovation, which recommends a way to decouple the application actions from the physical resources involved. These decoupling of resources are to be assisted by the perception of a 'virtual machine' which compresses an application with a definite set of performances. It is a perfect tool to improve energy efficiency of data centers with enabling to permit 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 which is installed as software, then it acts like a dedicated hardware. Usually, thousands of VMs are hosted in cloud data centers[6]. The allocation of VMs to PMs is a tough assignment in highly scalable environments, and thus may have create a great impact on the routine of the data centres. Each VM has its own characters and consumption features of distinctive amount of energy depending upon the usage of resources and thus emit dissimilar quantities of carbon footprint. The total amount of carbon footprint of the data center is relative to the energy practice by each host. The arrangement of the multiple VMs on the same physical machine facilitates in consolidating the mission and turning off other physical machines which will helps to cut down the energy consumption level to a great extent. Thus the multiple objectives should be considered , such as: improving the load balancing, maximization of resource utilization, minimization of energy consumption etc. while optimizing the whole cloud Quality of Services. Nearby years, researchers commenced to consider the networking aspects as one of the significant issues that influence the cloud data center deeds mainly related for acquiring energy efficiency.

V. VIRTUAL MACHINE MIGRATION

Virtual Machine Migration is one among the salient aspects of virtualization for efficient management of resources. The VM migration technique aids to shift virtual machines from one physical machine to another without the suspension of the VM. Migration is the potential means for the load balancing, cold spot migration as well as hot spot migration. Server consolidation or cold spot migration is the situation where the load on the host is below the lower threshold i.e., the server is considered as under loaded, and overloaded migration or hot spot migration is the situation where the active host in which virtual machine is running is not able to assure the requisites of the VM owing to its load is above the upper threshold value. VM Migration could be done by using different algorithm like first fit, best fit, worst fit, monte carlo, round robin etc. [7].

V. A. Techniques of Virtual Machine Migration

There are two categories of migration. They are:

- **Live Migration:** Live migration is the most outstanding feature of the Virtualization. It is facilitating the cloud provider to stabilize the system via migration. It helps to allot a VM to one PM to a new with little or no downtime for running activities and it is maintaining the network connections of the guest OS . User doesn't notice any interruption in service in hot (live) migration. Live migration and the SLA governing deals with the following disputes in dynamic VM consolidation[8]:
    - Determination of the overloaded host.
    - Determination of the underloaded host.
    - 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. The status of the VM loses and user can feel the service interruption. Through this migration, user has the option of moving the related disks from one data location to another based on their request. The VMs are not necessary to be on a shared storage.

VI. VIRTUAL MACHINE PLACEMENT

When a virtual machine is installed on a host machine, the procedure of picking the most advisable host for the virtual machine is called virtual machine placement. It is a critical process of determining the most appropriate physical host or server to host the VM. It entails by classifying the underlying hardware and network and other resources requirements together with estimated utilization of resources and the placement objective. The placement objective can either be optimizing the management of existing resources or it can be minimizing of energy consumption by switching off few servers provisionally. Selecting an appropriate host in important to ensure the

QoS parameter also. The virtual machine placement algorithms are to be designed to convene the aforementioned objectives or targets.
Subject to the target of placement, a VM placement algorithm can be classified into two kinds:

a. Power-based VMP: This algorithm is obtaining a VM to PM mapping which permits a system to be energy efficient and achieve highest resource utilization.

b. QoS-based VMP: This algorithm is obtaining a VM to PM mapping to assure and ensure the quality of service necessities to the users.

Subject to the need of migration, a VM Placement algorithm can be classified into two kinds:

a. Static VMP: In this technique, VM placement does not consider either the status of the virtual machines and physical machines, or frequency of the arrival rate of the user requests.

b. Dynamic VMP: This technique achieves optimal solutions from the current mapping of VMs at nominal cost.

VI. A. Energy Efficient VM Placement Methodologies

Following are the power- based algorithms that have been used to solve the VM placement problem to ensure the goal of energy efficiency:

a) VM Placement using Stochastic Integer Programming

Stochastic Integer Programming (SIP) is to be applied for modeling optimization problems that occupy a high amount of ambiguity. Stochastic means "having a random probability distribution or prototype that may be investigated statistically but may not be envisaged precisely."[10]. SIP is useful in cases where real rights are unknown, but the allotment of rights is identified or can be estimated. In SIP, there are 3 phases to assign resources:

   a. Reservation: Cloud broker supplies resources and approximate the requirement without the knowledge of the actual demand of users
   b. Utilization: The reserved resources are being used for the actual use of cloud service users.
   c. On-demand: In case the user demands exceed, the reserved resources - the additional resources - can be requested in an on-demand pay basis[12].

b) VM Placement using Constraint Programming

Constraint Programming is a widely used logical programming for combinational search problems where the results must be assured by the constraints on relations among variables. A set of constraints are fixed and they can be easily extended to involve and satisfy more requirements. The CP considers real world-problem as a constraints fulfillment problem and a general principle constraint solver analyzes result for it. Cloud service providers plan to mechanize the virtual machines placement by taking, the quality of service parameters of the applications into contemplation. It can be symbolized as a constraint programming problem.

c) VM Placement using Genetic Algorithm

The Genetic Algorithm (GA) is a population-based meta heuristic algorithm , begins with a initial set of population which applies evolution to get better mappings among VMs and PMs. It can also be termed as bin packing extended with added constraints. It is particularly applicable in situations where objective functions are dynamically changing.

d) VM Placement using Bin Packing

The bin packing-based VM placement among PMs can be utilized to locate the actual mapping of virtual machines to accessible physical machines[9]. It is feasible to cut back the running cost of active data centers by firmly packing the VMs necessitated to be ran at once onto the least number of PMs achievable.

Some popular solutions of VM placement 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[12].
- 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).
- Random Fit(RF): Randomly a PM is selected for placing VM. [10] If PM assures the resource requirement, VM starts on that PM. If it is not satisfied, another PM is randomly selected. This process will be continued for every VM.

VII. RELATED WORK

VII. A. Network-conscious virtual machine placement designs

Organizing numerous migrations from a solitary host in a specific period of time whilst the network traffic demand is at a topmost position, offers a challenging and tough dilemma, to such an extent that the cloud framework might not have sufficient assets openly accessible to meet the expansion in assets required. Accordingly, it will set aside a more extended time for various movements to be finished, which thus prompts execution debasements for VMs. In this way a host is reserved in an over utilized or under-utilized status for a supported period, influencing its Service Level Agreement(SLA), which is an agreement by the cloud supplier and client portraying the reaction time and throughput ensures.

The pioneer commitments on network-aware placement of VMs were expounded by Stage, A. et al.[11]. Depending on the learning with regard to network topology, VMs are put to streamline traffic flows in the interior of a data centre network. This advent permits work migration control amid runtime with a exclusively composed network-aware scheduler. The migration scheduler knows about the migration postponements and data transmission bandwidth requirements.

Baker,T. et al. [12] have analyzed a network-based routing algorithm - Green Director (GreeDi), which found the most energy efficient path to attain a complete green cloud computing network objective, while ensuring the customers demands, such as service response time by acting as a interconnection among the users' jobs and the green data centres . Linear integer programming approach was used to model the proposed algorithm. They designed three different structured routes, with regards to nodes, power along with capacity subject to the Chief POP and Central POP traversed which leading to any one of the green cloud data centres. Though they can take a judgment on which is the best energy efficient path that same one can only be finished after each victorious distribution and/or reception progression to ensure that the calculation has been completed depended on all the traversed nodes, and not only based on limit of any failure nodes. But they are not considering the time needed for transportation with energy and time needed for calculation between data centers and between consumers and data centres.

Cziva, R. et al. [13] have recommended SDN based S-CORE VM migration algorithm which explained that intersected server-network control structure to facilitate the SDN to organize live VM migration so as to minimize the network-based communication rate, of the arising traffic dynamics which cannot be predicted, and lighten overcrowding of the expensive, highly-oversubscribed links of the upper layer of a Cloud Data Centre topology. In S-CORE algorithm, link utilization and cost value are manually found out by the strength of pair wise traffic among VMs. But this algorithm is completely topology-neutral one and become static in nature. While implementing SDN dependency, all information is either already obtainable in the network or can be centrally constructed. Then the information effectively transmitted during the intact topology, whilst the kernel of the algorithm still hold its scalable and distributed behavior. Now the new converged algorithm is a scalable, topology-alert live migration algorithm that minimizes the communication charge of pair wise VM traffic flows by developing collocation and network locality. The blend of high speed networking and virtualization limits the SDN for what it can do such as it creates controller redundancy, failure behavior and interoperability between devices from multiple vendors.

Xu,G. et al. [14] have presented BEERS, a novel energy- efficient routing algorithm designed as a SDN controller application for data center networks. This algorithm can be scheduled traffic flows in to active and the queued status and each active flow assigned a feasible link with the help of SDN controller and the queued flow is wait for a assigned path become free. This strategy can be helped to cut down the energy for the specific degree of data center traffic for migrated VMs Placement. As a limitation of this algorithm is that they are only considering the typical DC Network with identical links and not taking consideration of variant links with different topologies and bandwidth.

Yang, T. et al.[15], have investigated a new algorithm called VPTCA - an energy-efficient data center network scheduling resolution - using GA that jointly considered the virtual machine placement as well as communication traffic design minimize the power consumption in a DC Network. In the traffic message layer, VPTCA ideally used switch ports along with link bandwidth to stabile the load and evade blockages, permitting the DC network to boost up its transmission capacity as well as saving a considerable quantity of network energy. The progression of GA stays the relationship, and inherits to the brood. Exclusively , they propose a two-tier DNA code technique along with a fresh crossover operator to guarantee that this ingrained relationship is not to be severely wrecked in the VM placement. Moreover, a vibrant routing table generation algorithm is established to keep provisional memory consumption of switches still in the huge-scale data center network traffic pattern.

Zhang,J., et al.[16] theoretically analyzed how much bandwidth is required for guaranteeing the total migration time as well as downtime of a live VM migration. After that they proposed a new transport control mechanism for guaranteeing the computed bandwidth. They are achieving these two objectives through modified pre-copy live migration algorithm. In this algorithm it is assumed that the page dirty frequency of each memory page is varying and the Cumulative Distribution Function of the pages' dirtying frequency is a reciprocal function. Finally, to assure the computed bandwidth needed by the live VM migration, A transport control protocol, a cost-aware bandwidth sharing mechanism by Allocating switch Buffer (rSAB), is designed. Due to this mechanism the bandwidth achieved from this reciprocal-related form ensures the estimated aggregate migration time and downtime. Moreover, the transport control mechanism guarantees that the live VM migration flows gain the projected bandwidth even if there are background flows.

Ferdausa, M.H. et al[17] addressed the issue related to network-based, multiple component application placement in huge data centers. It is considered as an optimization crisis. They proposed a Network and Data location-aware

Application environment Placement (NDAP) algorithm, a greedy heuristic approach that executes concurrent placement of VMs and various data elements relating to computing, network, and storage resource demands and capacity restraints with the target of diminishing the network rate arouse due to the VM placement resolution. Due to this algorithm, reduces the distance, that data packets necessitate to move in the data center network, in order to help in localize the network traffic as well as lessens communication overhead in the topper layer network switches. As an extension of the work, they are considering to create an suitable grouping and organization of the online and offline VM placement and migration procedures with the objective of efficient network bandwidth supervision.

Duggam, M. et al. [18] have investigated autonomous network aware VM migration strategy using reinforcement learning for the choice of VMs from an over-utilized host to reduce power consumption regarding of live migration in a data centre. The RL agent studies to observe the command of the network traffic to schedule a number of VM to migrate through an energy incentive function. More over, they achieved to perform the efficient VM migration at low network traffic time, reducing congestion at peak- times, and enhancing the practice of network resource at off peak times. As a weakness they were not consider the under utilized hosts and SLAV metric.

Yan, F. et al. [19] have presented a polynomial-time heuristic algorithm, named as the perturbation algorithm, is a congestion-aware paradigm as it identifies the bandwidth congestion in the VM deployment process and after that, carefully relocates the assigned VMs to remove congestion. Besides, they investigated embedding problems in generalizing the substrate topologies and then they dealt with VDC request with heterogeneous bandwidth needs. They claimed with simulation result that the algorithm balancing the tradeoff between performance and time complexity of the VM placement in divergent bandwidth. They interested to extend their work for embedding oversubscribed virtual clusters in common internet topology substrate DCNs.

Wang, R. et al.[20] have described network-conscious VM placement scheme – MAPLE - in which VMs within an ensemble that necessitate to be located on dissimilar servers are sited in a way that guarantees that the “effective bandwidth” i.e., “least amount of bandwidth essential by a traffic source to keep up particular QoS objectives” , accessible on the network pathway between servers is adequate. They argued with the experimental result that MAPLE characteristically prevails in assembly with QoS goals while concurrently assigning both computing as well as network resources in a productive approach. One drawback of this approach is that while at the adequate time of VM placement, it could be generate to sub-optimal VM placement over time, specifically if VM ensembles are arranging for a time periods.

Table 1: Analysis of Network-aware Energy Efficient VM Allocation Techniques

Author	Technique	Methodology	Achievements	Weakness
Dong, J. et al.[21]	Constraint Programming	Two-stage heuristic algorithms : MC-BT and BF-HC	i) The energy efficiency is increased due to less number of active PM's. ii) Improvement of network performance	High migration cost
Xia, Y. et al.[22]	Stochastic Integer Programming	stochastic-queuing network-based framework	Performance metrics such as VM task accomplishment time, consumption rate, and task denial rate with different workloads is considered which is able to quantify the conduct of the migration-authorized cloud in fallible environment	Instead of local task migration between PMs of same server, remote migration between unique cloud federations via the wide area network is not measured.

Dias, D.S. et al.[23]	Bin Packing	Virtual Machine Placement (VMP) algorithm	i. Optimum VM deployment ii. Improvement of network throughput iii. Moved the traffic from the core switches to the edge switches	Detailed analysis is not conducted about migrations how it will influence the data centre network or other VMs.
Wang , M. et al.[24]	Stochastic bin packing	Online packing algorithm	Reduced the number of active PMs by considering network devices with fluctuating bandwidth demands of VMs	Multiple resources are not considered
Yang , T. et al.[25]	Genetic Algorithm	Virtual Machine Placement and Traffic Configuration Algorithm (VPTCA)	While considering three operational cost parameters- VM assignment, traffic pattern, and computing and transmitting load balance, it is achieving : i) fast path establishment ii) low utilization of temporary store space iii) load balancing iv) more transmission capability with a lesser amount of energy consumption	Being the cost of extensive convergence time, real-time conclusion in DCN is not possible .

Table 2: Comparison of Network-oriented VM Placement Designs

Author	Minimization of Traffic between VMs	Minimization of Traffic between PMs	Minimization of Traffic between Data Centres	Minimization of Data Transfer Time	Bandwidth Management of VMs	Communication between VMs
Amendola,D. et al.[26]					✓	
da Silva, R. A.et al.[27]	✓		✓			✓
Liu, J.et al.[28]	✓	✓		✓	✓	
Jiang, J. W.et al.[29]	✓		✓	✓		
Duggan,M. et al.[30]			✓	✓	✓	

VIII. CONCLUSION

Cloud computing innovation is required to develop and give vast services and computational energy to end clients. In this setting energy effectiveness is more critical for virtualized data centres because of more power utilization, higher running cost and large amount of CO_2 discharge to the earth. Virtual Machine Placement in data centres of

the cloud environment has been a dynamic zone of research in the previous couple of years. This report enlighten the different placement algorithms and their execution assessment with regard to network-traffic consideration while taking account of VM placement in optimal places in dispersed geographical areas. The goal of these systems can minimization of energy consumption, maximization of resource utilization, enhancement of load balancing improvement of QoS and to achieve green cloud computing. The enthusiasm towards this subject rose in 2009 and keeps on drawing in researchers in the cloud computing enhancement territory.
During the literature survey, we note that, grading these algorithms or expressing the best one out of the many isn't an appropriate proposal in light of the fact that each one of other VM Placement method has some particular target, migration method, major resources and credible parameters. Despite the fact that these parameters may appear to be fine from external view, there may have a few or the other sort of tradeoffs when profoundly overviewed. Inferable from the workload changeability and ceaselessly changing structure and interests of applications, there is an obligation to persistently reform these VM placement techniques.

With the detailed discussion of this study related to live VM Migration while considering not only the least consumption of energy but also consciousness in network traffic, we reach a conclusion that the majority of the investigations have a tendency to mitigate the network traffic in both initial placement and migration forms of VMs. Not very many papers considered the multi-target issue however none of them utilized a multiobjective way to deal with settle it. The effect of network resources - switches, routers etc-, usage on power utilization and the time-changing requests are likewise components infrequently centered around.

A more profound examination of data centre network architecture and topology, resource properties and qualities may bring forth different variations as a future scope and give inventive ways to deal with take care of down to earth issues.

Acknowledgments

The authors would like to acknowledge and thank all people who help them in different ways to fulfill their research work.

REFERENCES

[1] Jansen, W., & Grance, T. (2011). Sp 800-144. guidelines on security and privacy in public cloud computing.(Accessed October 2017)

[2] www.independent.co.uk/environment/global-warming-data-centres-to-consume- three-times-as- much- energy-in-next-decade-experts-warn-a6830086.html energy consumption of data centres 2016.

[3] “Limiting Global Climate Change to 2 degrees Celsius – The way ahead for 2020 and beyond”, publications.europa.eu/ resource/ uriserv/l28188.ENG(Accessed October 19, 2017)

[4] Murugesan, S., & Gangadharan, G. R. (2012). *Harnessing green IT: Principles and practices*. Wiley Publishing. ISBN: 978-1-119-97005-7

[5] https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index- vni/complete-white-paper-c11-481360.html, Cisco Global Cloud Index, 2015–2020, Synergy Research Group(Accessed November 5, 2017)

[6] Buyya, R., Broberg, J., & Goscinski, A. M. (Eds.). (2010). *Cloud computing: Principles and paradigms* (Vol. 87). John Wiley & Sons. ISBN: 978-0-470-88799-8.

[7] Beloglazov, A., & Buyya, R. (2013). 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*, *24*(7), 1366-1379.

[8] Malik, V., & Barde, C. R. (2015). Live migration of Virtual Machines in Cloud Environment using Prediction of CPU Usage. *International Journal of Computer Applications*, *117*(23)..

[9] Han, Y., Chan, J., Alpcan, T., & Leckie, C. (2017). Using virtual machine allocation policies to defend against co-resident attacks in cloud computing. *IEEE Transactions on Dependable and Secure Computing*, *14*(1), 95-108.

[10] Choudhary, A., Rana, S., & Matahai, K. J. (2016). A Critical Analysis of Energy Efficient Virtual Machine Placement Techniques and its Optimization in a Cloud Computing Environment. *Procedia Computer Science, 78*, 132-138.

[11] Stage, A., & Setzer, T. (2009, May). Network-aware migration control and scheduling of differentiated virtual machine workloads. In *Proceedings of the 2009 ICSE workshop on software engineering challenges of cloud computing* (pp. 9-14). IEEE Computer Society.

[12] Baker, T., Al-Dawsari, B., Tawfik, H., Reid, D., & Ngoko, Y. (2015). GreeDi: An energy efficient routing algorithm for big data on cloud. *Ad Hoc Networks, 35*, 83-96.

[13] Cziva, R., Jouët, S., Stapleton, D., Tso, F. P., & Pezaros, D. P. (2016). SDN-based virtual machine management for cloud data centers. *IEEE Transactions on Network and Service Management*, *13*(2), 212- 225.

[14] Xu, G., Dai, B., Huang, B., Yang, J., & Wen, S. (2017). Bandwidth-aware energy efficient flow scheduling with SDN in data center networks. *Future Generation Computer Systems*, *68*, 163- 174.

[15] Yang, T., Lee, Y. C., & Zomaya, A. Y. (2014, December). Energy-efficient data center networks planning with virtual machine placement and traffic configuration. In *Cloud Computing Technology and Science (CloudCom), 2014 IEEE 6th International Conference on* (pp. 284-291). IEEE.

[16] Zhang, J., Ren, F., Shu, R., Huang, T., & Liu, Y. (2016). Guaranteeing delay of live virtual machine migration by determining and provisioning appropriate bandwidth. *IEEE Transactions on Computers*, *65*(9), 2910-2917.

[17] Ferdaus, M. H., Murshed, M., Calheiros, R. N., & Buyya, R. (2017). An algorithm for network and data-aware placement of multi-tier applications in cloud data centers. *Journal of Network and Computer Applications*, *98*, 65-83.

[18] Duggan, M., Duggan, J., Howley, E., & Barrett, E. (2017). A network aware approach for the scheduling of virtual machine migration during peak loads. Cluster Computing, 1-12.

[19] Yan, F., Lee, T. T., & Hu, W. (2017). Congestion-Aware Embedding of Heterogeneous Bandwidth Virtual Data Centers With Hose Model Abstraction. *IEEE/ACM Transactions on Networking (TON)*, *25*(2), 806-819.

[20] Wang, R., Wickboldt, J. A., Esteves, R. P., Shi, L., Jennings, B., & Granville, L. Z. (2016). Using empirical estimates of effective bandwidth in network-aware placement of virtual machines in datacenters. IEEE Transactions on Network and Service Management, 13(2), 267- 280.

[21] Dong, J., Wang, H. & Cheng, S.,(2015) Energy-performance tradeoffs in IaaS cloud with virtual machine scheduling, Communications, China, 12(2), pp.155-166.

[22] Xia, Y., Zhou, M., Luo, X., Pang, S., & Zhu, Q. (2015). Stochastic modeling and performance analysis of migration-enabled and error-prone clouds. *IEEE Transactions on Industrial Informatics*, *11*(2), 495-504.

[23] Dias, D. S., & Costa, L. H. M. (2012, December). Online traffic-aware virtual machine placement in data center networks. In *Global Information Infrastructure and Networking Symposium (GIIS), 2012* (pp. 1-8). IEEE.

[24] Wang, M., Meng, X., & Zhang, L., (2011).Consolidating virtual machines with dynamic bandwidth demand in data centers.In *IEEE INFOCOM, 2011 Proceedings IEEE* pp. 71-75, 2011.

[25] Yang, T., Lee, Y., & Zomaya, A. (2015). Collective energy-efficiency approach to data center networks planning. *IEEE Transactions on Cloud Computing*.

[26] Amendola, D., Cordeschi, N., & Baccarelli, E., (2016). Bandwidth management VMs live migration in wireless fog computing for 5G networks. In *Cloud Networking (Cloudnet), 2016 5th IEEE International Conference* on (pp. 21-26). IEEE.

[27] da Silva, R. A., & da Fonseca, N. L. ,(2016). *Topology-aware virtual machine placement in data centers*. Journal of Grid Computing, 14(1), 75-90.

[28] Liu, J., Guo, J., & Ma, D., (2016). Traffic Aware Virtual Machine Packing in Cloud Data Centers. In *Big Data Security on Cloud (Big Data Security), IEEE International Conference on High Performance and Smart Computing (HPSC), and IEEE International Conference on Intelligent Data and Security (IDS), 2016 IEEE 2nd International Conference* on (pp. 256-261). IEEE.

[29] Jiang, J. W., Lan, T., Ha, S., Chen, M., & Chiang, M. (2012). Joint VM placement and routing for data center traffic engineering. In *INFOCOM, 2012 Proceedings IEEE* (pp. 2876- 2880). IEEE.

[30] Duggan, M., Duggan, J., Howley, E., & Barrett, E. (2016). A reinforcement learning approach for the scheduling of live migration from under utilised hosts. *Memetic Computing*, 1-11.

Authors' Profile

Sajitha A V is a Ph.D fellow in Department of Computer Applications in Noorul Islam Centre for Higher Education of Noorul Islam University at Kumaracoil , Tamil Nadu, India. She has received a Commerce with Taxation degree from University of Kerala, Kerala, India and MCA degree from Indira Gandhi National Open University. Her research interests include Computer Networking and algorithms in Cloud Computing to establish a Green Cloud Computing environment.

Dr. A C Subhajini is currently working as an Assistant Professor of Computer Applications in Noorul Islam Centre for Higher Education of Noorul Islam University at Kumaracoil , Tamil Nadu, India. She has received M.S. in Information Technology from Bharathidasan University, India in 2002 , M.Phil. in Computer Science from Alagappa University, India, 2005 and Ph.D in Computer Science from Mother Teresa Women's University, India, 2014. Her research interests include Cloud computing, Networking, Image processing and Data Mining. She has published more than 10 papers in International Journals.

Correspondence Author – Sajitha A V, sajitha_a_v@yahoo.co.in