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A review of Green Cloud Computing Techniques and Algorithms

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***Abstract-* Cloud computing is gaining importance in the present day world with increased usage of computers and computing power. Cloud computing deals with a number of virtual machines linked to various data centers spread across a cloud. While cloud computing techniques/algorithms facilitate many advantages to the user community, it also penalizes in terms of energy consumption and quality of service. In the context of realizing a unique cloud computing technique/algorithm, the paper presents a summary of the work done and the need for a greener cloud computing technique/algorithm which satisfies minimum energy consumption, minimum carbon emission and maximum quality of service.**

***Keywords*—Cloud computing, virtual machines, energy efficiency, energy consumption, performance.**

I. INTRODUCTION

The present-day use of computer technology and the Internet all over the world, in terms of speed, bandwidth, and other quantified parameters, demands larger and larger computing facilities with better utilization of resources. These problems can be alleviated through the use of cloud computing concepts [1],[2]. All cloud computing service providers are using virtual machines (VMs) as the main methodology for server consolidation. This has proved to be one of the most important techniques to help reduce the number of physical machines in any organization. Cloud computing has been defined [3]-[6] as a combination of hardware and software accessed over the Internet. The resources of cloud computing are managed by service providers (through third parties) who offer software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) [7]-[9].

Cloud computing can be deployed on four different models which allows flexibility of choice to the users. The four deployment models are as follow: (See Fig. 1)

- Private Cloud: This model can be deployed exclusively for an organization or leased to organizations by cloud service providers.
- Public Cloud: This is a type of deployment which can be shared by multiple organizations. It always consists of mega-scale infrastructures. It is owned and managed by service providers.
- Hybrid Cloud: This deployment model is composed of more than one deployment (private, community and public). For example an organization can choose to lease a public deployment from a service provider while maintaining in-house infrastructures (private) or leases from a service provider.
- Community Cloud: This allows sharing of infrastructures for specific organizations or communities. For example the ministry of health can deploy a community cloud for all ministries of health and hospitals around the country. It can be managed solely by an organization or leased by service providers.

Cloud computing allows different organizations, from different parts of the world, to share and access an unlimited pool of resources on demand.

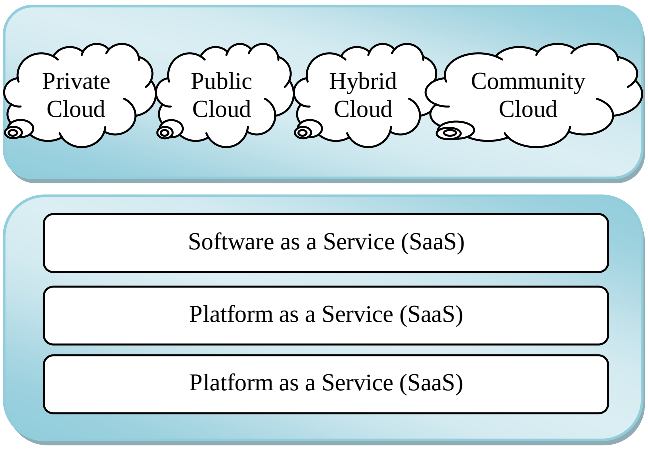

Fig. 1: Cloud deployment and service model.

II. PROBLEM THEME

Since the domain of research in the area of cloud computing is wide, the main focus of this paper is on energy consumption, carbon emission and performance in aggressive virtual machines consolidation (VMC). In order to ensure quality of service (QoS) and energy efficiency, server VMs consolidation problems become the main focal point. Research carried out suggests that the lack of proper planning in the use of cloud computing can cause serious problems [10]-[13] While the users of cloud computing benefited from 90% energy savings and zero utilization of physical resources, delivery of services from providers to consumers still poses a challenge. Since cloud providers host physical and VMs consolidated resources, energy consumption and carbon emission still remain a challenge.

There are other reported cases of energy consumption [14]-[18] which increases dramatically in Asia Pacific and other parts of the world. Data centers are responsible for 2% of carbon emissions globally and this number is estimated to climb to 18% by the year 2020. Greenpeace, the United States Environmental Protection Agency and the Climate Server Computing Initiatives [15] have taken steps to make servers more *energy efficient*, in addition, other initiatives of power management techniques of dynamic voltage frequency scaling (DVFS) have also been proposed [19]. The involved technologies depend on hardware, and are not controlled according to the needs of the cloud providers.

A large amount of research effort has been made by various authors [20]-[28], with the aim being to reduce energy consumption while ensuring a better quality of service (QoS). However, there are performance issues in achieving reduced energy consumption which need to be tackled. The majority of the researchers have considered CPU as the main component for utilization, which therefore becomes unrealistic to judge performance and power consumption without first considering that the primary memory utilization is not efficient.

The results of practical research implemented at the Caledonian College of Engineering (Oman) show massive server VM consolidation performance, not to be based on the CPU utilization alone [29]. Primary memory is an important component which must be taken into consideration [30]-[31] as well. Most of the techniques/algorithms are implemented through simulation; they do not tackle the problem of energy consumption and performance very effectively.

In order to achieve greener VM consolidated cloud computing, more research is still needed to improve the energy efficiency of data centers [32]. The motivation of this paper is based on data centers rather than cloud computing clients.

III. RELATED WORK

The existing research has proposed better heuristics, techniques and algorithms that control the utilization of VMs in servers so as to make cloud computing greener, and more efficient.

Authors in [33] have proposed a research on reducing energy consumption in cloud infrastructure which allows the number of physical servers (PMs) to be minimized. It allows the VMs to be moved to a limited number of servers in order to allow the concentrated physical servers to utilize the maximum resources and setting other servers to a low power mode. An algorithm was developed which migrates the VMs from an empty server in order to maximize the power consumption. It is based on a gossiping protocol that sprints from time to time in order to spot the current situation of the VM allotment, and uses the live migration features provided by the virtual machines monitors' management to complete the migrations. The algorithm mostly considers the number of VMs operating on each server. It will check the capability of a certain server through gossiping to determine if it can allow migration to happen from a source server, which will have to make sure the destination server is not full before the migration. It uses peer-to-peer (P2P) service to gossip in order to determine the current VMs hosted by a particular server. Though the algorithm is able to detect the number of VMs in each physical machine, it is rather difficult to judge when and how the physical machines become overloaded or under loaded, without setting up parameters such as CPU, memory and network bandwidth usage. Authors [34]-[36] have identified various issues with performance problems in data centers to be an unpredicted workload sent by cloud consumers; most of the performance issues discussed were caused by unpredicted usage of CPU, memory and network bandwidth. As that is the case, our work will be focusing on setting up CPU and memory parameters based on the practical experiment, which might give an exact estimation on when the CPU and memory becomes overloaded, under loaded or idle. The study in [37]-[38] suggests a similar technique of migration in the VMs from numbers of physical machines available in the data centers (DCs) and squeezing them to other physical machines which do not seem to be fully packed. Although the concepts look similar, their techniques vary from that of [33].

VM migration has been considered to be the strategy of saving energy and improving the QoS in DCs [39]-[40]. Authors in [41] have proposed VMs placement and used a modified best-fit decreasing algorithm which allow VMs to be sorted based on usage of CPU in decreasing order; which is quite different from the research in [21] which was based on millions of instructions per second (MIPS). They have introduced the use of a threshold system, which is believed to be the better solution to preventing the resources from being over utilized. Higher and lower utilization have been considered rather than just one alone (higher utilization), which will always allocate the VMs to physical machines (PMs). They have suggested using dynamic migration of VMs, which will fit the changing behavior of VMs. In addition, three methods have been suggested so as to make a decision on which VMs will need to be migrated:

- Minimization of migration: a few numbers of VMs migrate so as to reduce migration overhead
- Highest potential growth: the VMs that seem to have the lowest CPU usage are migrated
- Random choice: choosing the essential number of VMs in a random manner

As per the algorithm, they have suggested a gossiping protocol with two threads (Active and Passive) which is similar to that of [23] that decides the number of VMs a particular PM can handle.

The authors have also reviewed the general power model that helps to identify which components of cloud computing consumes energy when the workload increases. Different components such as physical machines (PMs) with VMs, storage, and network components, have been reviewed in terms of energy consumption. Though they have not considered all of the above factors, they have mainly focused on CPU usage, which is considered to be the most important factor in terms of utilization. The algorithms allow equal distribution of resources and prevent migration overhead. Based on this idea, it is very obvious that the utilization of resources will be minimized, which allows energy consumption to be reduced. In order to minimize the utilization of resources better, our work will focus on two components, CPU and memory utilization which we believe can be used to reduce energy consumption and improve performance.

The authors in [21] have also proposed an idea by considering a cooling system and the racks of the network structure that hold the physical servers which goes beyond the normal components in VM migration. They have employed four different algorithms to achieve less energy consumption, quality of service, and optimal placement of VMs. The four different algorithms detect the underutilized and non-underutilized server by selecting the number of VMs from the VMs list by using the *Modified Best Fit Decreasing algorithm* (MBFD), which places VMs in the rack-by-rack algorithm, VMs in the non-underutilized rack algorithm, and migrates VM on underutilized racks consecutively. The whole process uses millions of instructions per second (MIPS) based on users request. Their objective is to take care of consolidation issues which would minimize the number of active racks, which will in turn switch off the unused racks, cooling systems and idle servers after proper migrations have been performed. The research has claimed to improve energy to an average of 14.7% in the entire data center.

Though the authors have considered most of the components that may help in reducing energy consumption and improve performance, it is not very clear how the algorithms will predict the unpredictable tasks sent by cloud users within a 24 hour period as the algorithm has been set to operate on minimum and maximum levels. Our research will improve this aspect by focusing on a practical experiment that will estimate the close percentage of utilization that will trigger when the server will become overloaded, under loaded and idle. We will also consider CPU and memory utilization percentage rather than MIPS.

The other research has taken a different approach, which involves memory reusing mechanisms for dynamic VM consolidation [31] in order to reduce the amount of transferred data during migration. They have claimed that the existing live migration techniques take a long time to migrate since they have to transfer the entire image of the memory from one host to another. They have two types of physical hosts; a shared server that handles VMs, which doesn't take on a heavy computation load (close to idle server), and dedicated servers, which take active VMs. In the case that all the VMs happen to be idle, they will be consolidated to the shared servers. If all the VMs happen to be active, they will require higher performance, which means they will need to be transferred to the dedicated servers in order to maintain performance.

As the VM migration happens many times in cloud systems, they claimed there is a very high chance that VMs will migrate to the original host, as has been executed before. For instance, if the VMs happen to move from an idle state to a busy state, there is a need for VMs to be moved from the shared server to a dedicated server to maintain performance. In order to avoid the total transfer of memory from one host to another, an image of memory from one host (i.e. from host Y) can be left and reused when the VMs are transferred back as shown in Fig. 2

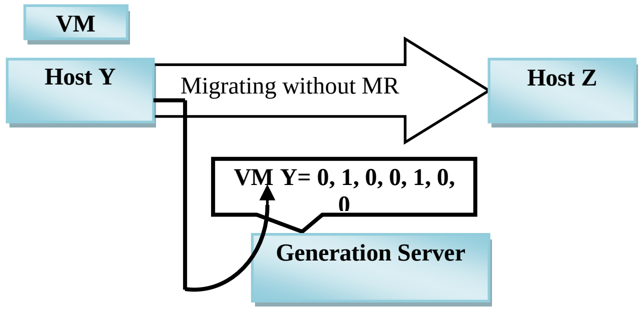

Fig. 2: Migrating VM without memory reuse.

Figure 2 shows migrating without memory reuse (MR) during the first transfer; the memory image is stored on the source host (Y). It updates the generation table and the algorithm will know which pages can be reused. Adapted from [31]

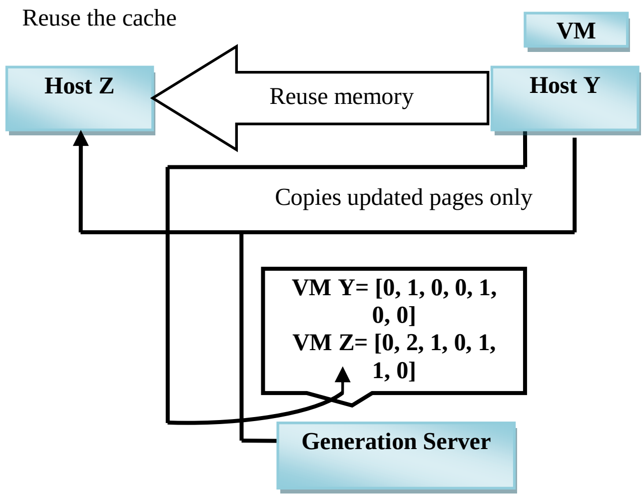

Fig 3: Migrating VM with memory reuse.

Figure 3 shows migrating with memory reuse (MR) to host Z, which was migrated the first time. During the migration there is no need for transferring all the pages. The VM will reuse the memory, which was previously cached in host Y. Adapted from [31]

Since the proposed idea is unique and works in two ways, the system may be able to improve its performance better than a complete image transfer, if the cloud systems are to work as predicted by the authors. This idea may work in an environment where there are a minimal number of hosts and where the original host migration will be easily returned. If comparison is made to the data centers, such as Google and Amazon, it may not always be possible to return to the original location due to the massive availability of servers. In order to be used in a large environment of DCs, our approach will prefer the complete image transfer of memory and CPU utilization from which we believe the delay and better energy consumption might be enhanced.

An algorithm for a greener cloud computing has been proposed [42] by mimicking the behavior of honeybees. They have made an observation on overloaded, under loaded and idle CPUs. The major problem of this algorithm is to find the proper way of managing the idle CPU, the under loaded CPU, and the overloaded CPU. They have introduced proper management of overloaded, idle and under loaded CPUs with the aim of turning off the idle CPUs and scheduling the task of the overloaded CPU to the under loaded CPU, for the purpose of saving energy and preventing quality of service violations.

The research has divided the jobs into two parts; the first part deals with the management of under loaded and overloaded CPUs, in order to reschedule the tasks. The second part deals with the idle CPUs for the purpose of reducing the power consumption.

The research undertaken by [42] seems to be good, since they have performed practical experiments by using Ubuntu (Linux). The framework proposed is well-organized and linked to the algorithms proposed. The framework is designed in stages and allows cloud consumers to utilize the service based on the limitation and agreement with the cloud providers.

They have used a threshold value of the CPU which is the best way to judge whether the servers are becoming overloaded or under loaded. However they suggested turning off the idle machines which may not be a very good idea; if the CPU is turned off for a short time and then rebooted, it tends to consume more electricity, reduce performance and increase the wear-and-tear of server components [43]. The other issue is that if the under loaded CPUs become overloaded by an unexpected request, how will an idle server ensure the quality of service without interruption, since it has to take the process of rebooting into account? As that is the case, our research will propose to put the idle servers into power saving mode to improve performance and reduce energy consumption.

Authors in [44] propose an energy-aware analysis, which is based on RAM utilization (RAM-based host overloading detection), which is quite different from [41] and [45] which are concentrated on the usage of CPU through its utilization and millions of instructions per seconds. Through this research, [44] has claimed to have improved energy consumption by 37.26% and 70% in performance, due to the migration of VMs.

They have also developed a policy for energy awareness of RAM-consolidated VMs selection. Data center brokers and cloudlets have been created based on the utilization values. VMs, which will be found to have minimal utilization, will be considered to have migrated to other servers.

In order to ensure that the energy and quality of service is maintained, [44] has developed an algorithm that will detect the over-utilization and underutilization of hosts, and implement RAM consolidation with local regression techniques, which will evaluate the performance of the host that is combined with the VM selection algorithm. They have redesigned the schedule for the cloudlets in order to get the information of each application. The RAM of each VM has been sampled and added up in each host from the VMs scheduler.

If we consider the technique [44] of RAM-based overloading detection, it is very clear that the algorithm and the equation suggested will help in improving the performance of the data center. Since the utilization of VMs is calculated by adding the required amount of RAM of the cloudlets, which operates in the VMs and is then divided by the total capacity of RAM in a particular VM, it may not be that easy when applied to the huge environment of data centers where millions of users are involved and the task from each user is unpredictable. In addition to that, the technique is able to improve performance and reduce energy consumption as they have considered primary memory alone and living CPU which is considered to be an important component in performance and energy consumption [46]. To overcome this problem, our research will use both components (RAM and CPU) which will also improve performance and reduce energy consumption.

Authors in [33] proposed a novel technique for dynamic consolidation of VMs that are based on the adaptive utilization of the CPU threshold. They have used dynamic threshold utilization, which means the system will be able to adjust based on the behavior of the workload sent by the users. Thus, the system utilization threshold will be based on a history of utilization during the lifetime of the VM operation. This technique is different from the other research, which considers the fixed value utilization of the CPU [29],[47]-[50] This novel technique claims to reduce energy consumption and ensures the quality of service to cloud users. The SLA violation claims to be as low as 1%.

Due to live migration of VMs, authors they have considered the service violation, and have predicted the cost of live migration to be 10%. Based on this claim, they have proposed a dynamic threshold with a heuristic algorithm that minimizes the number of VM migrations.

The proposal of dynamic threshold utilization [27] has provided a different view that will enable a better performance by adjusting the system speed based on the load given by the users. However it may be not easy to limit the VMs migration in an environment of cloud usage such as Amazon or Google, but if migration is limited, there will be performance problems based on the over-utilization of the CPU. Our proposed approach will ensure there is a good balance between the overloaded and under loaded servers which will in-turn put idle servers to sleeping mode.

The authors in [18] have come up with a proposal that may help to evaluate server consolidation so as to improve the power efficiency, while ensuring that the QoS is maintained, particularly in large data centers. The model proposed is trying to address the application workload and considers the effect of energy and QoS while turning on/off the servers and the migration of virtual machine from one data center to another.

It mostly concentrates on resource usage (CPU, memory usage and I/O activities). According to the simulation results from the two data centers, which involve 400 concurrent VMs, they claim to have reduced the energy consumption by 50% while ensuring that the QoS is maintained.

The model can improve performance and energy consumption if the allocation of resources in each data center is done systematically. The process is very long, which will in turn consume more energy and absolutely reduce performance. There will be no good reason for terminating the service due to SLA violation after all the processes have failed. The designed agents appears to be fine, but the technique seems to take a longer time, thus making it difficult to match the reality of cloud computing. The technique may work better if the decision of migration is made after the maximum point where the load is not acceptable.

IV. A GENERAL PROPOSED FUTURE APPROACH

Though a lot of research is being undertaken to reduce energy and ensure quality of service, the uses of energy consumption, carbon emission and delivery of quality service are still present and require more attention to ensure cloud computing becomes greener. The recent research done by [51] still proved high consumption of energy in cloud computing. Energy consumption is not only an issue since consumers of cloud computing are still complaining and doubting the operation speed of cloud computing.

Moreover there are still more problems on consolidation. Indeed a lot of research and techniques have not specified how consolidation is better planned and how VMs are allotted based on different load sent by different users. The matter is not consolidating VMs on one, two or more physical machines, but consolidation needs critical estimation that will not overload the physical machines and at the same time ensuring the energy is saved. The other important issue is how VMs will be provisioned to take certain tasks from the clients, the problem of utilizing resources to the maximum still persist as the quality of service is not up to the standard of satisfaction, based on the practical aspects, one should consider when and where VM will be overloaded and how to ensure VMs are not overloaded or under loaded. There are many physical machines as well as virtual machines which are not fully utilized; many services are still distributed separately, leaving lots of idle servers being operated and wasting lots of electricity as well as emitting carbon which pose a threat to our environment.

In order to have Greener Cloud Computing**,** more active research needs to be done with emphasis on practical experiments. The work involves design and development of a unique techniques/algorithm which will not only reduce energy consumption and lower carbon emission by considering scheduling and machines provisioning, but it will also ensure better quality of service by taking care of consolidation issues that will satisfy clients and ensure 24/7 service availability. The consolidation issue will be considered practically based on the type and number of VMs used. CPUs utilization and primary memory will need to be allotted to different consolidated VMs based on the size, speed of CPU and RAM. A technique based on the consolidation problem needs to be designed in order to allow data of different capacity to be dynamically allotted to VMs which will be of acceptable CPU and primary memory utilization. After tackling the problem of consolidation, VM provisioning will be another issue; a technique/algorithm will be designed to allow virtual machines not to be used more than overload capacity of total CPU, and primary memory usage. The technique should divert the VMs to other machines when it reaches overload capacity of utilization. By designing this technique, better energy consumption may be achieved and at the same time it will ensure better service to the clients. The other important issue is to consider the scheduling mechanism, designing a technique that will prevent physical machines and virtual machines being used un-necessarily. The technique will be able to monitor unused server (both physical and virtual machines) by putting them in a sleepy mode as well as alerting them to a standby mode in order to be ready to take the incoming tasks.

V. CONCLUSION

In this paper, a detailed review of existing cloud computing algorithms/techniques has been given and the gaps are identified. It is observed that many data centers are still consuming energy, emitting carbon and causing performance degradation to the data centers and end users. Lack of proper planning has resulted into many data center's servers to be utilized inefficiently. The significance of proper planning and a unique greener cloud computing technique/algorithm will be proposed to satisfy the needs for energy consumption, carbon emissions and quality of service to the data centers and end users.

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