AN ANALYSIS UPON ENERGY EFFICIENT TECHNOLOGIES IN GREEN CLOUD COMPUTING: RECENT TRENDS

International Journal of Information Technology and Management

Vol. X, Issue No. XV, May-2015, ISSN 2249-4510

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

International Journal of Information Technology and Management
Vol. X, Issue No. XV, May-2016, ISSN 2249-4510

An Analysis upon Energy Efficient Technologies in Green Cloud Computing: Recent Trends

Ashutosh Bhatt[1] Dr. Priti Dimri[2] Ambika Agarwal[3]

[1]Assistant Professor, Uttarakhand Technical University

[2]Professor and Head of MCA Department, Govind Ballabh Pant Engineering College, Ghudauri, Uttarakhand

[3]Assistant Professor, Uttarakhand Technical University

Abstract – Cloud computing is an "evolving paradigm" that has redefined the way Information Technology based services can be offered. It has changed the model of storing and managing data for scalable, real time, internet based applications and resources satisfying end users' needs. More and more remote host machines are built for cloud services causing more power dissipation and energy consumption.

Cloud computing is a highly scalable and cost-effective infrastructure for running HPC, enterprise and Web applications. However, the growing demand of Cloud infrastructure has drastically increased the energy consumption of data centers, which has become a critical issue. Data centers hosting cloud computing applications consume huge amounts of energy, contributing to high operational costs and carbon footprints to the environment. With energy shortages and global climate change leading our concerns these days, the power consumption of data centers has become a key issue. Therefore, we need green cloud computing solutions that can not only save energy, but also reduce operational costs.

- - - - - - - - - - - - - - X - - - - - - - - - - - - - -

INTRODUCTION

The cloud computing is the talk of town in it industry in present years. the reports daily emerge displaying the benefits of usage of this new computing model based on grid computing. it handles multi-level virtualization and abstraction through effective integration of several computing resources, data, storage, applications and other related infrastructure so that the user just makes a wayout with minimum pay-as-per-usage basis. at the same time with the usage of more it based strategy there is alongside a load on the environment as the carbon footprint is enhanced. thus ultimately the balance for usage and the load on environment has to be maintained, hence an energy efficient mechanism for cloud computing platform has to be developed.

Cloud computing is a model that enables convenient, ubiquitous and on-demand network access to a shared pool of configurable computing resources (like networks, servers, storage, its applications, and services) that can be speedly provisioned and released with minimal management effort or service provider interaction. Cloud computing achieve multi-level virtualization and abstraction through effective integration of variety of computing, storage, collection of data, applications and other resources, user-friendly to use powerful computing and Storage capacity of cloud computing only need to connect to the network. The cloud computing has made situation far better .With cloud computing virtual network, the capability of handling millions of users becomes easy. These characteristics have attracted many IT giants like Amazon , Google ,Microsoft , Intel, VMware etc. Amazon is currently providing two services first Amazon S3 a Simple Storage Service and Amazon EC2 Elastic Cloud Computing. Therefore a lot of new applications are deployed on internet every day and numbers of people using these services are growing rapidly. The increase in demand of new users for accessing applications in public and personal level. Personal level like social networking which produce a huge work load and public level includes private corporations and public organizations. To manage load technology like virtualization had evolved which had made computing more compelling than previous years. It has been observed that the consumption had been doubled since year 2000. These of surveys has given birth to a new advocacy called green computing which is growing with the aim to make the system energy efficient and efficient utilization of resources. Studies shows average utilization of data centers can be nearly 20% and energy consumed by the idle resources is can be as much as 60% of the peak power. Virtualization technology improves power efficiency of data centers by enabling the assignments of multiple virtual machines (VMs) to single server. The assignment of multiple VMs helps in consolidating the task and turning off other physical machines there by lowering the consumption of energy. Another way for green computing is through service level agreement SLAs which is established between the service provider and the consumer before allocation of infrastructure. The SLA could be related to storage space, bandwidth, and power consumption. On basis of performance SLA could be related to service time and Quality of Service. Virtual Machine Migration is another green computing technique for efficient usage of resources. The VMM technique migrate virtual machines from one machine to another this will help in distributing load from one physical machine to another. After the CPU utilization decreases it will migrate the VM back to the machine and turn off the second machine. This helps in lowering the electricity consumption by physical machines. Since the machine will consume energy when required else it is turned off. VMM could be done by using different algorithm like first fit, montecarlo, round robin etc.

Significant savings in the energy budget of a data centre, without sacrificing service level agreements, are an excellent economic incentive for data centre operators, and would also make a significant contribution to greater environmental sustainability.

According to Amazon.com's estimates, at its data centres, expenses related to the cost and operation of the servers account for 53% of the total budget (based on a 3-year amortization schedule), while energy-related costs amount to 42% of the total, and include both direct power consumption (~19%) and the cooling infrastructure (23%) amortized over a 15-year period.

Dennis Pamlin, the Global Policy Advisor ofWWF, Sweden highlighted different IT solutions and their beneficial impact on greenhouse gases (GHG), which include CO2, emissions. These opportunities include IT- based solutions: e.g. smart buildings, smart transportation and communication, smart commerce and services, and smart industrial production.

The colloquial term 'smart' in this case means 'with low carbon footprint', showing that the adoption of such 'smart' IT solutions will enable a potentially large GHG reduction, including information and communication technologies (ICT) itself which is a large power consumer (and therefore a GHG emitter), and IT solutions that have a huge potential impact in reducing GHG emissions in many sectors (Fig. 1).

Based on a recent 'Data Centre Energy Forecast Report', it can be expected that savings of the order of 20% can be achieved in server and network energy consumption with respect to current levels and that these savings may induce an additional 30% saving in cooling needs as detailed in a study by HP and the Uptime Institute. It shows that 'most of data centre power is spent on cooling ICT equipment (between 60 and 70%)'.

Thus there are very significant economic and environmental gains to be obtained from a serious research thrust on energy efficiency in the general area of IT and computer networks. In particular, cloud computing is an inherently energy-efficient virtualization technique, in which services run remotely in a ubiquitous computing cloud that provides scalable and virtualized resources. Thus peak loads can be moved to other parts of the cloud and the aggregation of a cloud's resources can provide higher hardware utilization.

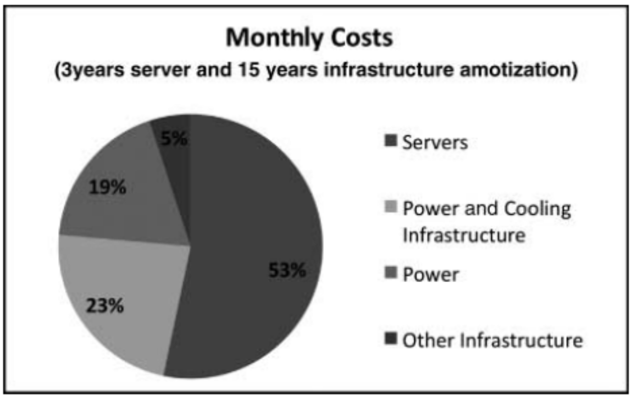

FIGURE 1. Energy Distribution in the Data Centre

The cloud computing is characterized in three basic service models: Infrastructure as a Service (IaaS)-. This provides on demand IT infrastructures as services over the computer network. Examples of IaaS are AmazonEC2, GoGrid and Flexiscale. The second model is Platform as a Service (PaaS) - It provides operating system support and software development framework.

Examples- Google App Engine, force.com .The third model is Software as a Service (SaaS)-It provides on demand applications over the internet. Example of SaaS providers' are- Oracle on Demand, Salesforce.com, Google Apps.

With the huge capacity to store bulk data in huge data centers, computing and providing services, cloud computing leads to increase in energy consumption which releases greenhouse gases in the environment with high carbon footprint. The need of an hour is to manage the energy consumption across the entire information and communication technology (ICT) sector. Cloud computing if significantly managed without sacrificing service level agreements, can potentially lead to overall energy saving and contribute towards the Green Cloud in a sustainable environment manner. Data Energy Forecast Report has shown that we can expect the savings of order 20% in server and network energy consumption.

GREEN COMPUTING

The aim of this research is to help the organizations who want to move their applications to the cloud to find the most energy efficient architecture for the applications and their data contributes in reduction the footprint and carbon emissions which indeed resulted in reduction of the pollution and making the environment greener. This section will discuss the green computing topic which is the second main relevant theoretical topic related to the research after the cloud computing. Moreover, a deep discussion will be shown about the green computing aspects in cloud computing, and whether the cloud computing itself is a green idea or not.

Green computing is also known as green IT, refers to environmentally sustainable computing or IT whose goal mainly to maximize the energy efficiency and reduce the use of hazardous material. Green computing focuses on reducing resource consumption and disposing the electronic waste in a responsible way. To achieve these purposes, green computing is applied in all aspects related to the computer systems such as implementing of energy-efficient central processing units (CPUs). Green computing is the study and practice of designing, manufacturing, using and disposing of computers, servers, and related peripherals efficiently and effectively with minimal impact on the environment.

Based on the definition of green computing in the previous subsection, Green Computing can be addressed in four dimensions: Green use, Green disposal, Green design, and Green manufacturing as shown in Figure 2.

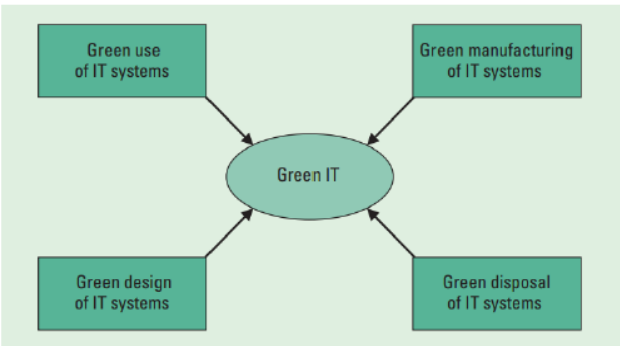

Figure 2: Green IT dimensions

Modern IT systems compose of a complicated mix of people, network, hardware, software. Thus, green computing initiative has to cover all of these areas. In the next sub-sections, some of these approaches will be discussed. The following represents environmentally sound practices applied in some dimensions shown in Figure 2. The following are some approaches applied in green design and manufacturing of IT systems.

Data Centers Design: The accelerated increasing in the numbers of Internet and Webbased applications leads to the fast growth in the data centers. In the last decade, the number of the server computers installed in data centers increase to 30 million.

Moreover, the electricity consumed by these new servers is more than the old ones. Beside the environmental impact of expanding the data centers, there is a huge increase in the cost of operating these data centers as the cost of energy is growing continuously. Furthermore, the availability of the electrical energy is a critical problem for many companies. Therefore, the social, financial, and the practical constraints force businesses and IT departments to reduce the energy consumption of these data centers.

Software Optimization by Algorithmic Optimization: The efficiency of the algorithms has a great impact on the resources required to compute computer programs. For example, by changing the search algorithm from linear search to a binary, hashed, or indexed search can reduce resource usage for a given task. According to a study has been made by a physicist at Harvard, Google search emits seven grams of carbon dioxide (CO_2). However, Google opposes this figure, arguing instead that a typical search produces 0.2 grams of carbon dioxide (CO_2).

Virtualization: Virtualization is the key strategy to decrease the power consumption of data centers. The virtualization technology built based on the idea that one physical server hosts multiple virtual servers. Virtualization technology simplifies the data centers, makes them using less electricity, and reduces their energy demands by hosting multiple virtual machines on a small number of more powerful servers. Many enterprises are using virtualization to curb the runaway energy consumption of data centers.

Power Management: There are some power management systems that can allow an operating system to control the power consumption of the underlying hardware. Such systems can automatically switch off components such as hard drives and monitors after set periods of idleness. Moreover, a system may hibernate by turning off most components including the central processing unit (CPU) and the system memory (RAM). The Advanced Configuration and Power Interface (ACPI) and the earlier Intel-Microsoft Advanced Power Management are example of such power management standards.

Ashutosh Bhatt[1] Dr. Priti Dimri[2] Ambika Agarwal[3]

ARCHITECTURE OF GREEN – CLOUD COMPUTING

People in IT industry are reassessing data center strategies to determine if energy efficiency should be added to the list of critical operating parameters.

Issues of concern include:

1. Reducing data center energy consumption, as well as power and cooling costs
2. Security and data access are critical and must be more easily and efficiently managed
3. Critical business processes must remain up and running in a time of power drain or surge

These issues are leading more companies to adopt a Green Computing plan for business operations, energy efficiency and IT budget management. Green Computing is becoming recognized as a prime way to optimize the IT environment for the benefit of the corporate bottom line – as well as the preservation of the planet. It is about efficiency, power consumption and the application of such issues in business decision-making. Simply stated, Green Computing benefits the environment and a company's bottom line. It can be a win/win situation, meeting business demands for cost-effective, energy-efficient, flexible, secure and stable solutions, while demonstrating new levels of environmental responsibility.

A. Cloud:

Cloud computing is becoming one of the most explosively expanding technologies in the computing industry today. It enables users to migrate their data and computation to a remote location with minimal impact on system performance. These benefits include:

1. Scalable - Clouds are designed to deliver as much computing power as any user wants.
2. Quality of Service (QoS) - Unlike standard data centres and advanced computing resources, a well-designed Cloud can project a much higher QoS than typically possible.
3. Specialized Environment - Within a Cloud, the user can utilize custom tools and services to meet their needs.
4. Cost Effective - Users finds only the hardware required for each project.
5. Simplified Interface - Whether using a specific application, a set of tools or Web services, Clouds provide access to a potentially vast amount of computing resources in an easy and user-centric way.

B. Cloud Infrastructure:

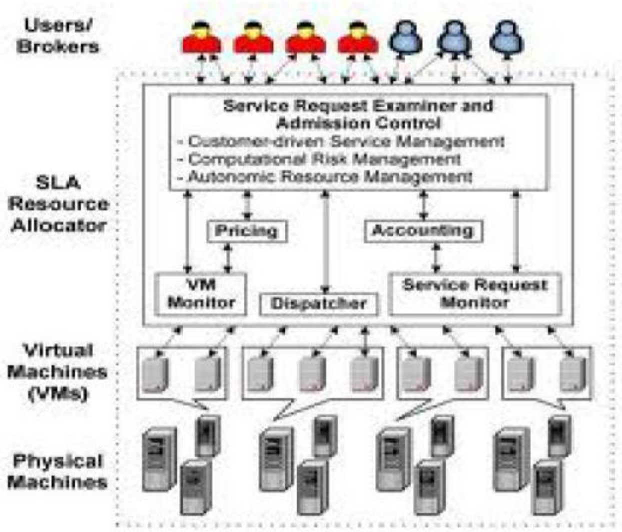

Fig 3. The high level system Architecture.

In Cloud computing infrastructure, there are four main entities involved:

1. Consumers/Brokers: Cloud consumers or their brokers submit service requests from anywhere in the world to the Cloud. It is important to notice that there can be a difference between Cloud consumers and users of deployed services.
2. Green Resource Allocator: Acts as the interface between the Cloud infrastructure and consumers. It requires the interaction of the following components to support energy-efficient resource management:

Green Negotiator: Negotiates with the consumers/brokers to finalize the SLA with specified prices and penalties between the Cloud provider and consumer depending on the consumer's QoS requirements and energy saving schemes.

Service Analyser: Interprets and analyses the service requirements of a submitted request before deciding whether to accept or reject it.

Consumer Profiler: Gathers specific characteristics of consumers so that important consumers can be granted special privileges and prioritized over other consumers.

Pricing: Decides how service requests are charged to manage the supply and demand of computing resources and facilitate in prioritizing service allocations effectively.

Energy Monitor: Observes and determines which physical machines to power on/off.

Service Scheduler: Assigns requests to VMs and determines resource entitlements for allocated VMs. It also decides when VMs are to be added or removed to meet demand.

VM Manager: Keeps track of the availability of VMs and their resource entitlements. It is also in charge of migrating VMs across physical machines.

Accounting: Maintains the actual usage of resources by requests to compute usage costs. Historical usage information can also be used to improve service allocation decisions.

3. VMs: Multiple VMs can be dynamically started and stopped on a single physical machine to meet accepted requests, hence providing maximum flexibility to configure various partitions of resources on the same physical machine to different specific requirements of service requests.

Multiple VMs can also concurrently run applications based on different operating system environments on a single physical machine.

4. Physical Machines: The underlying physical computing servers provide hardware infrastructure for creating virtualized resources to meet service demands.

C. Green Cloud Architecture:

As discussed above, cloud computing platform as the next generation IT infrastructure enables enterprises to consolidate computing resources, reduce management complexity and speed the response to business dynamics. Improving the resource utilization and reduce power consumption are key challenges to the success of operating a cloud computing environment. To address such challenges, we design the Green - Cloud architecture and the corresponding Green Cloud exploratory system. The exploratory system monitors a variety of system factors and performance measures including application workload, resource utilization and power consumption, hence the system is able to dynamically adapt workload and resource utilization through VM live migration. Therefore, the Green-Cloud architecture reduces unnecessary power consumption in a cloud computing environment.

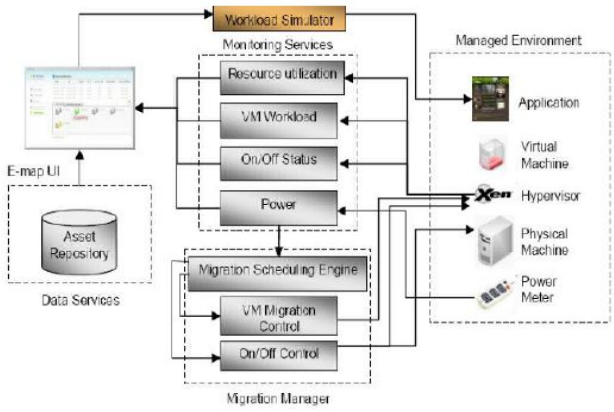

Fig 4. Green – Cloud architecture

demonstrates the Green - Cloud architecture and shows the functions of components and their relations in the architecture.

NEED OF GREEN CLOUD COMPUTING

Modern data centers, operating under the Cloud computing model are hosting a variety of applications ranging from those that run for a few seconds (e.g. serving requests of web applications such as e-commerce and social networks portals with transient workloads) to those that run for longer periods of time (e.g. simulations or large data set processing) on shared hardware platforms. The need to manage multiple applications in a data center creates the challenge of on-demand resource provisioning and allocation in response to time-varying workloads. Normally, data center resources are statically allocated to applications, based on peak load characteristics, in order to maintain isolation and provide performance guarantees. Until recently, high performance has been the sole concern in data center deployments and this demand has been fulfilled without paying much attention to energy consumption .Data centers are not only expensive to maintain, but also unfriendly to the environment. High energy costs and huge carbon footprints are incurred due to massive amounts of electricity needed to power and cool numerous servers hosted in these data centers. Cloud service providers need to adopt measures to ensure that their profit margin is not dramatically reduced due to high energy costs.

Lowering the energy usage of data centers is a challenging and complex issue because computing applications and data are growing so quickly that increasingly larger servers and disks are needed to process them fast enough within the required time period. Green Cloud computing is envisioned to achieve not only efficient processing and utilization of computing infrastructure, but also minimize energy consumption. This is essential for ensuring that the future growth of Cloud computing is sustainable. Otherwise, Cloud computing with increasingly pervasive front-end client devices interacting with back-end data centers will cause an enormous escalation of energy usage. To address this problem, data center resources need to be managed in an energy-efficient manner to drive Green Cloud computing. In particular, Cloud resources need to be allocated not only to satisfy QoS requirements specified by users via Service Level Agreements (SLA), but also to reduce energy usage.

ENERGY EFFICIENCY

When we relate cloud with green computing, the question arises that whether cloud is green or not. The research by Accenture in 2010 has shown that moving business application to cloud can reduce carbon footprints of organizations. According to the report – Small business saves up to 90 % carbon emission. Mid-size business saves 60 to 90 % carbon emission. Large business saves at least 30-60 % carbon emission.

On contrary, in same year Greenpeace observed that cloud lead to increase in problem of carbon emission and global warming and the reason given is collective demand of computing resources increases in few years and cloud providers are interested in electricity cost reduction than carbon emission reduction. The data collected is shown in 1 below and no datacenter can be said as energy-efficient by this report.

Datacenter	Effective Power Usage	Dirty Energy	Renewable Energy
Google	1.21	50.5% coal, 38.7% Nuclear	3.8%
Apple	1.21	50.5% coal, 38.7% nuclear	3.8%
Microsoft	1.22	72.8% coal, 22.3% nuclear	1.1%
Yahoo	1.16	73.1% coal, 14.6% nuclear	7%

Table 1. Comparison of Cloud Datacenters.

The growth of cloud computing is increasing with time in IT sector. Thus impact of it on environment is important research field today.

ENERGY EFFICIENCY OF CLOUD INFRASTRUCTURE

In this section we put data center equipment in the context of energy efficiency by describing existing problems. Further, we describe state of the art approaches used for tackling these problems. Finally, we highlight future challenges that are yet to be solved.

A. Network

Network serves as a bridge between end users and Cloud resources such as computation and storage. Its energy consumption is distributed over three main systems, namely the connections inside a data center, the network between data centers, and the outside fixed and wireless network that allows end users to access services via mobile devices. Within a data center, the network currently accounts for up to 10% of the operating expenses that include power consumption, and is estimated to rise to 50% due to increased Internet traffic. This is due to a large number of network units, and their unproportional power usage while running idle. Moreover, poor network architectures not suited for Cloud applications can increase energy waste by unnecessary re-routing the traffic or keeping some parts of the network underutilized.

First step of improving the energy efficiency is to upgrade network equipment by implementing power saving modes and adaptive transmission rates, in order to achieve proportional power usage. This can additionally reduce a head load of the equipment and hence reduce the energy consumption of the supporting cooling system, as well as improve its reliability. In case of zero utilization, unused ports, links and switches can be switched off completely. However, such approaches usually lead to performance degradation due to reduced connectivity. Tweaking the network equipment is usually insufficient, as even the most efficient equipment can waste energy due to poor network topologies. Flexible topologies that allow dynamic routing paths require fewer components, while still exhibiting high resilience to failures. Consequently, the network traffic can be spread amongst multiple paths, or sent through few energy-critical paths, while letting other parts of the network to enter low-power modes. Such a scheme is used for inter data center networks as well, by exploiting uninitialized network bandwidth for bulk transfers, which create less communication overhead compared to the separate network packages.

B. Servers

Servers include computing and storage servers placed inside enclosures/cabinets, as well as its components such as processors, memory, disks, etc., excluding the communication equipment that is part of the network. The power density of a single rack of servers started in range between 250 W to 1.5 kW in 2003. In 2014 it reached almost 10 kW and is projected to rise up to 30 kW until 2020. Moreover, most servers consume over 50% of their peak power consumption while running idle, while their average utilization is typically as low as 10-50%. Consequently, an infrastructure operating at only 20% capacity may consume 80% of the energy as the same infrastructure operating at 100% capacity. Such numbers become alarming when considering that only in the last quarter of 2013 over 2.5 million new servers where shipped. Therefore, improving energy efficiency of the servers represents a top priority task.

Similar to network equipment, servers can also benefit from power proportional components, where power and performance is automatically scaled based on a current load. Most prominent technology includes Dynamic Voltage and Frequency Scaling (DVFS) found on today's CPUs, which provide P-states (power modes while being utilized), as well as sleep C-states (power modes while being idle). The same applies for other components such as memory and storage disks, which can be put to a low power state while being idle. In order to increase idle time of disks, modern hardware utilizes onboard cache controllers, where reads and writes are performed prior from/on cache. If data cannot be found in cache, only then the disk is accessed. Furthermore, cache itself can be optimized by dynamically reconfiguring its size and associativity, or even turning off parts of cache that are not used, thus reducing static power consumption (also known as leakage power). Finally, new low-power cache technologies can be integrated along with the existing ones, thus reducing the energy consumption while maintaining the performance.

C. Cloud Management System (CMS)

Due to increasing energy consumption of ICT, monitoring and management of Cloud supporting infrastructures is recognized as the main concern within a data center facilities. Therefore, the main role is assigned to the Cloud management system (CMS) in order to improve efficiency, increase utilization, and thus lower the energy loss/waste within a data center.

The CMS includes scheduler, monitoring system and virtualization technology, which allows running multiple virtual machines (VMs) on top of a single physical machine, and thus increases utilization. However, a trade off of the latter is an energy consumption overhead as it adds additional software layer, namely a hypervisor. Similarly, a monitoring system creates an overhead as well, through monitoring agents and probes while collecting monitoring information required for managing the infrastructure.

The main purpose of the CMS is scheduling and load balancing the underlying infrastructure, more specifically servers, VMs and applications. In the context of VM management, as the most prominent example of Cloud services, several actions can be taken for improving energy efficiency. First includes a VM self-adaption and hardware adjustment, where a VM reconfigures its resources based on the current load. Additionally, using more lightweight virtualization technologies such as Linux containers is shown beneficial in many cases. Selecting most efficient physical machines for VM placements is considered as the second optimization action. Final action includes VM migrations, which allows dynamic consolidation of physical machines by moving underutilized VMs on fewer hosts and powering of unused ones. Such rescheduling of VMs over time enables reduction in resource consumption at any given moment.

D. Appliances

Appliances represent operating systems, platforms and applications accessed and utilized by end-users. On one hand, efficiency of appliances is only considered for Software (SaaS) and Platform as a Service (PaaS), since an appliance is then under control of the provider and thus part of the Cloud Computing infrastructure. On the other hand, for lower level services such as Infrastructure as a Service, an appliance is deployed by an user, and therefore the user is responsible for its efficiency. Since applications run on top of operating systems and runtime environments such as Java Virtual Machine, latter ones usually create overhead in resource consumption and thus energy consumption. However, performance of the applications can have even greater impact on energy usage, as applications exhibiting poor performance require more instances and therefore more servers, which consume additional amount of energy.

Recommendations and techniques for developing energy efficient software with focus on reducing power consumption of idle appliances are provided by Agrawal et.al. Moreover, by limiting wake-up events and changing timer activities idle time can be increased, and hence power consumption reduced. For instance, using push instead of a pull mechanism allow the software to remain dormant until action is actually required. Additionally, avoiding memory leaks and removing unused features improves software efficiency in terms of ratio between resource consumption and the amount of useful work performed. Furthermore, improving compilers to include cache skipping, use of register operands, instruction clustering and re-ordering, and loop optimization can improve code execution. Finally, optimizing software with regards to hardware resources can significantly improve energy efficiency, e.g., implementing batch access to resources such as disk, hence decreasing number of unnecessary wake-ups.

CONCLUSION

As the prevalence of Cloud computing continues to rise, the need for power saving mechanisms within the Cloud also increases. This paper presents a Green Cloud framework for improving system efficiency in a data center. To demonstrate the potential of framework, presented new energy efficient scheduling. Though in this paper, we have found new ways to save vast amounts of energy while minimally impacting performance. Not only do the components discussed in this paper complement each other, they leave space for future work. Future opportunities could explore a scheduling system that is both power-aware and thermal-aware to maximise energy savings both from physical servers and the cooling systems used.

The author have discussed briefly about the energy efficiency of cloud computing. The survey of energy management of cloud computing, metrics of green cloud, overall energy consumption model and green cloud architecture is also done. Various researches have been there for green cloud computing and the work on reducing power consumption in datacenters is still in progress but cloud cannot be claimed as green. Cloud computing is accepted worldwide due to its cost efficiency but is it worth risking the environment.

REFERENCES

A.Berl and de H. Meer, (2009). “An energy –efficient distributed office environment,” Proc. European Conference Universal Multi server vice Networks, IEEE Computer Society Press, Sliema, Malta.

Anton Beloglazov and Rajkumar Buyya (2010). “Energy Efficient Allocation of Virtual Machines in Cloud Data Centers” 10th IEEE/ACM International Conference on Cluster, Cloud and Grid Computing.

Baliga, Jayant, et al. (2011). "Green cloud computing: Balancing energy in processing, storage, and transport." Proceedings of the IEEE 99.1. pp. 149-167.

Berkeley (2013). “The energy efficiency potential of cloud-based software,” http://crd.lbl.gov/assets/pubs presos/ACS/cloud efficiency study.pdf.

Buyya, R., Yeo, C.S. and Venugopal, S. (2008). Market-oriented Cloud computing: Vision, hype, and reality for delivering it services as computing utilities. Proceedings of the 10th IEEE International Conference on High Performance Computing and Communications, Los Alamitos, CA, USA.

Buyya, R., Yeo, C.S., Venugopal, S., Broberg, J., Brandic, I. (2009). “Cloud computing and emerging IT platforms:” Vision, hype, and reality for delivering computing as the 5th utility. Future Generation Computer Systems 25(6), pp. 599-616.

C. Hewitt. “ORGs for scalabe, robust, privacy-friendly client cloud computing,” IEEE Internet Comput., pp. 96-99, September.

Chen, Feifei, et al. (2013). "Experimental analysis of task-based energy consumption in cloud computing systems." Proceedings of the 4th ACM/SPEC International Conference on Performance Engineering. ACM.

Chen, Feifei, et al. (2014). "Automated analysis of performance and energy consumption for cloud applications." Proceedings of the 5th ACM/SPEC international conference on Performance engineering. ACM.

Emerson (2014). “Energy logic 2.0: New strategies for cutting data center energy costs and boosting capacity,” Emerson Network Power, Emerson Electric Co., Emerson Network Power, Ohio, USA, Tech. Rep..

Foster, Y. Zhao, I. Raicu, and S. Lu. (2008). “Cloud Computing and Grid Computing 360-Degree Compared,” in Grid Computing Environments Workshop, 2008. GCE’08, pp. 1–10.

Garg, Saurabh Kumar, and Rajkumar Buyya (2012). "Green cloud computing and environmental sustainability." Harnessing Green IT: Principles and Practices, pp. 315-340.

Greenpeace (2010). “Make IT Green: Cloud computing and its contribution to climate change,” Greenpeace International, Tech. Rep..

Greenpeace International (2010). Make IT Green http://www.greenpeace.org/international/en/publications/reports/make-it-green Cloud computing/

Hewitt C. (2008). ORGs for scalable, robust, privacy-friendly client cloud computing. IEEE Internet Comput., September, pp. 96–99.

Kaur et al., (2014). International Journal of Advanced Research in Computer Science and Software Engineering 4(9), September - 2014, pp. 818 821.

L. Wang, G. von Laszewski, A. Younge, X. He, M. Kunze, and J. Tao (2010). “Cloud computing: a perspective study,” New Generation Computing, vol. Wang LYAH, to appear in 2010.

Mell, P. and Grance, T. (2009). The NIST Definition of Cloud computing, National Institute of Standards and Technology.