An Analysis Report on Green Cloud Computing Current Trends and Future Research Challenges

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A R T I C L E I N F O

Article history:
Received 11 January 19
Received in revised form 28 January 19
Accepted 22 February 19

Keywords:
Green cloud computing,
Cloud computing,
Virtualization,
Energy efficiency,
Multi Tenancy

A B S T R A C T

Today cloud computing became an impressive solution to address the challenges in storage and process of high volume data, with low-cost, high-speed, on-demand and pay-per-use characteristics. Although rapid progression has been recorded in the area of cloud computing and its services, attaining the implementation of green clouds is still under development due to lack of research and several barriers in its implementation. Green clouds are committed to design as eco-friendly, energy efficient, max resource utilizable, low carbon emissions, long lasting and recyclable. In order to satisfy the ever growing enterprise data storage and processing needs, the cloud service providers are coming up with cutting edge technologies like Green Cloud Computing in cloud architecture design to reduce, the huge power consumption, water consumption, need of physical hardware peripherals, infrastructure and harmful carbon emissions etc. To protect our environment from cloud negative impacts, the service providers must adopt and update their cloud infrastructure towards green computing. Green computing researches widely focus on designing of efficient clouds with green characteristics like Power Management, Virtualization, High Performance Computing, Load balancing, Green data center, Reusability, Recyclability etc. As part of my research on green clouds, this paper presents an analysis report about the green cloud computing and its characteristics in detailed manner. This paper thoroughly discusses about the former green computing achievements, current trending concepts of green computing and future research challenges as well. This comprehensive green cloud analysis report helps the naïve green research fellows to learn about green cloud topics and to understand the green cloud future research challenges.

Peer review under responsibility of International Conference on Sustainable Computing in Science, Technology and Management.

1. Introduction

Since a decade cloud computing became the popular computation platform for business organizations and helps the entrepreneurs to concentrate on their essential business operations instead of investing their time and money on infrastructure management. According to NIST (Peter Mell and Tim Grance, 2011), the cloud computing offers various services like IaaS, PaaS and SaaS, to attract the business applications owners in adopt and migrate the cloud services to their business app modules as presented in figure 1. Cloud based data centers, platforms, servers and the other infrastructure services are enough elastic to supply the sudden demand of huge resources from customers. As per Heininger (Heininger R, 2012) the cloud offering distributed deployment models, pay-per-use charging policy, on-demand connectivity, high speed networks and low-cost resources are aiding in adoption of new organizations to cloud, from multinational to small-scale level.

Today most of the gadgets like smart phones, tablets, smart watches, health care devices and the sensors are connecting to clouds for their private data storage purpose. Most of the software applications like e-mails, messengers, enterprise apps, social web networks, e-cart apps, audio and video streaming apps, broad-casting and entertainment services are utilizing the cloud services to store, process, share and secure their data. The most popular search engine giant Google hosted all of its services like Gmail, Google Earth, Google Drive, Google Play and YouTube on their personal cloud platform (GCF) to offer the high quality services to its worldwide customers. In September 2018, Forbes published the cloud statistics (Forbes & Gartner survey, 2018) revealed that, the worldwide public clouds revenue value is 175.8 billion dollars now. With the growth rate of 17.3% the public cloud revenue is forecasted to record 206.2 billion dollars in 2019, is indicating the fastest growth rate of cloud utilization worldwide. Amazon web services (AWS), Microsoft's Azure, Google cloud platform, IBM Cloud are the popular cloud services offering vendors in today cloud market.

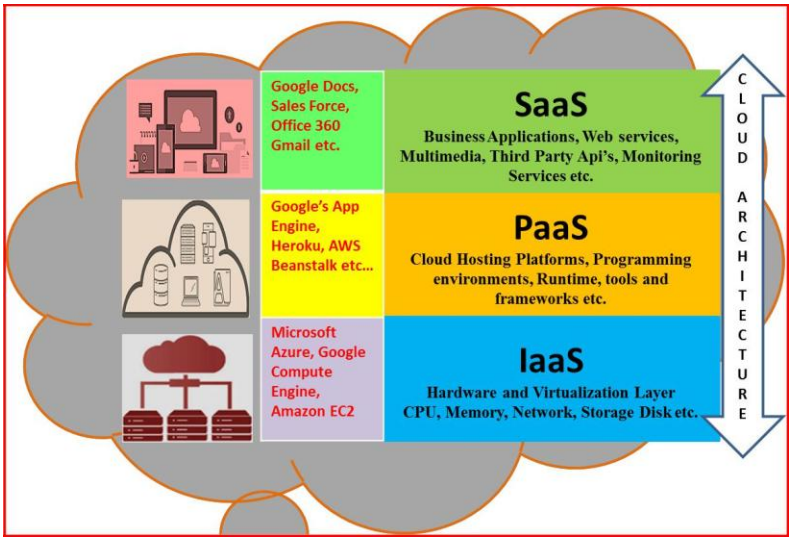

Fig. 1 - Cloud Computing Service Layers Architecture

However the elastic nature of cloud is satisfying the needs of cloud service consumers, the service providers are suffering from tolerating the huge power consumption by data centers, which further leads to high operational cost, emission of more carbons and less profits. Clouds are addressing the majority of the problems encountered by today business organizations, but they are suffering from few notable limitations are huge power consumption, more CPU idle times, need of deploying the resources at upper bound, emission of carbon gases and producing huge electronic waste (e-waste) material. Henceforth there is a need of developing today cloud environment as eco-friendly like "Green Cloud Computing". The general cloud computing mainly concentrates on storing and processing of data efficiently, whereas the term green cloud computing is a novel reform in cloud computing which is introduced with the main goal of transforming the cloud environment as eco-friendly (Hilty M.L, & Arnfalk P, et al, 2006). The main characteristics of green clouds are energy efficiency, virtualization, multi-tenancy (high-end utilizable), consolidation, automation, resiliency, recyclability and sustainability of cloud resources. World's green nature must not be affected by the naïve innovations like cloud computing, henceforth the experts are strongly recommending that the "cloud computing must consider the ecology gaining along with economy".

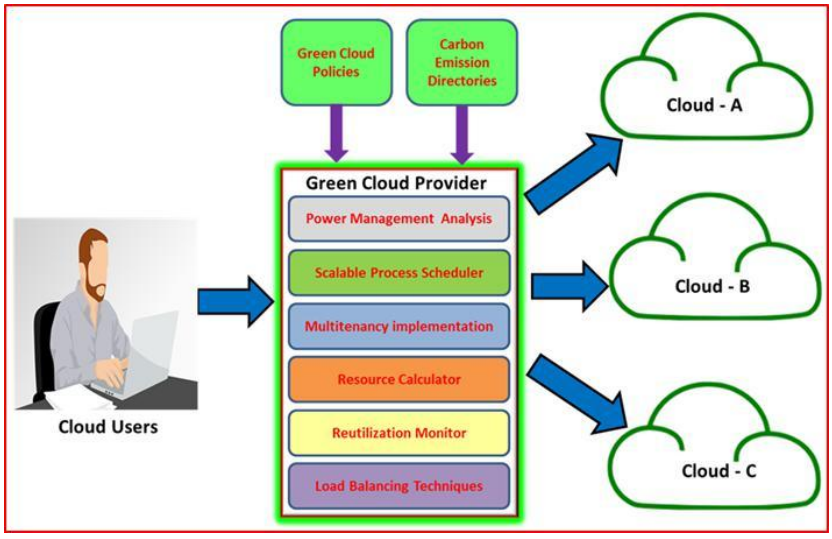

Fig. 2- Green Cloud Computing Architecture

Green cloud computing aims on designing the cloud environment as eco-friendly means the cloud should not exploit the greenness of the nature in any way. For example, a cloud environment is strictly following the energy efficient power management standards and policies to save the power, but it relies on coal based thermal stations for power supply, leads to an indirect damage to the nature. Hence the green cloud policies and standards must be designed by considering the direct and indirect negative impacts of clouds on ecology. Apart from the policies and standards, a set of monitoring tools and technologies are required to design the green cloud architecture. Figure 2 presents the essential tools and technologies used to design the green cloud computing architecture.

Aforementioned green cloud computing architecture designed with the Cloud Data Centres (i.e. cloud-A, Cloud-B and Cloud-C), Green Cloud Provider and Cloud Users etc. Cloud data centres are the standard cloud environments, designed to offer the cloud services like IaaS, PaaS or SaaS etc. The Green Cloud Provider (GCP) designed as a cloud service broker module, which is an authenticated module and allowed to monitor the cloud infrastructure and activities to certify the associated clouds as green. As part of its job GCP monitors the power management at each cloud level, by installing the module level energy consumption meters. After receiving the power consumption information from monitors, GCP analyses the consumption details with analytics and suggests the energy efficient power management solutions. Scalable process scheduler creates the virtual instances of cloud at run time to process the incoming request with high speed and accuracy. These virtual instances are used to enhance the ability of hard ware infrastructure by utilizing them at max possible level. Custom job scheduling algorithms are used in this process scheduling for enabling the parallel processing. Apart from few notable big organizations, the other cloud clients are belongs to small or medium scale industries. They are unable to set up their own IT Infrastructure with huge capital investments; hence they are approaching the clouds to deploy their applications for storing and processing their data. In this case, the public clouds must be designed securely, to support a pool of cloud users to host their applications on common cloud instance and sharing the cloud resources among them. This process is called as Multi Tenancy in cloud computing.

GCP module having resource calculator is another important cloud monitoring tool, which is deployed at each cloud instance level to record the utilization values of memory, CPU, Storage, bandwidth and time. This recorded information will be analysed, using the respective resource calculation algorithms to assess the future resources demand, resources underutilization, resources availability etc. Reutilization monitor is a high level examiner designed to propose the possible reutilization options of cloud resources to save the time and cost. Similarly the load balancing module concentrates on balancing the load (of Memory and CPU) across the multiple cloud instances while processing data to assure the smooth processing. Green cloud policies and carbon emission directories are the third party policy preparation groups. Their designed policies and standards help to construct the green clouds from normal cloud environments. Finally the end user is an IT manager of any organization, who can communicates with GCP to discuss about hosting their organization applications on green cloud and he plans the migration process of their IT applications with green clouds based on service level agreements (SLA).

2. Literature Review

As part of our research analysis on “Green Cloud Computing”, we thoroughly verified many journals, conferences, white papers, web sources to get the extreme valid content about green cloud computing and its characteristics. In this section we present the literature review on green cloud computing with the help of its relevant former research publications. Each notable research activities in the area green cloud computing are explored in brief with author details. This information helps the naïve research scholars to understand about the evaluation of green cloud computing and the improvements it had since beginning.

Pat Boher at el (Pat Bohrer, Elmootazbellah et al., 2002) conducted a research on optimal power management techniques, while operating the web servers at their low level of utilization, without any effect on its performance. They considered the system logs as the main input sources, to get the energy consumption values of a web server at various levels of utilization. They introduced an efficient power simulation mechanism to monitor the CPU and other resources consumed energy values, which helps in forecasting the future energy requirements. David brooks (D. Brooks, M. Martonosi et al. 2001), designed “Dynamic Thermal Management” method with CPU level clock gating techniques. This helps to run the main processer with max-low power, but the experiments on this method noticed that, it slightly impacts on CPU performance. In 2001, Jeffrey (J. Chase et. al, 2001) proposed the” energy-conscious provisioning” method, to dispatch the load of the incoming request to the idle servers, to save the energy and to utilize the resources evenly. This method spreads the load of a request evenly on all possible instances to complete the operations at high speed (as committed in SLA). In this case the resources are sharing the actual process among them to come out from the underutilization of resources problem. Jonathan G (J.G. Koomey, 2007) conducted a study on USA data centers consuming power values along with the other computational devices consuming power values. With this data he estimated that, by 2005 the power consumption value of data centers is 0.65% of total US generating power.

John Judge at el (John Judge, Jack P, Anand E & Sachin Dixit, 2008) published a white paper on energy efficiency, to explain how to reduce the power consumption of data centers without effecting on the server performance and availability. Finally he suggested that the utilization of possible low voltage resistant processors, deployment of power management tools (to monitor and auto management of power), virtualization techniques (to increase the processing power with same resources), design of blade servers and efficient cooling mechanisms are the best practices to design energy efficient clouds. Eduardo (Pinheiro Eduardo, Bianchini Ricardo et al, 2001) published an article on implementing the load balancing and unbalancing techniques in cluster

based systems, to reduce the power consumption and to improve the processing speed. They designed the cluster based system with an "on & off mechanism" to automate the turn on and the turn off operations based on the need of power. At server level and the operating system level this mechanism was implemented and recorded the good results in resources optimization. Luca Benni et al (L. Benini, A. Bogliolo & G.D. Micheli, 2000) conducted a survey on system level design techniques to improve the performance of cloud dynamic power management (DPM) procedure. As part of their survey they thoroughly revised the former researches on various system level dynamic power management methods. This knowledge helps them to understand about how the current power management techniques are working with limitations and how the future dynamic power management techniques to be designed to achieve the better performance. They described the System Component level power management, System level power management, Network level power management and they proposed some notable dynamic power management techniques in detail.

In 2010 Dzmitry (D. Kliazovich, P. Bouvry, Y. Audzevich & S. U. Khan, 2010) designed an NS-2 based simulator to record the power consumption at green cloud data centers. He performed some experiments with that simulator to record the power consumption values of cloud with Intel Xeon 4-core processor, 8MB DDR3 RAM and the 3.33GHz of cache value. They simulated and monitored the servers, routers, links, switches and workloads to determine the power consumption at each entity level. This simulation environment collected different cloud components related important power consumption statistics like extreme high/ low power usage values at each component, component idle state power usage, component average power usage etc. From their simulations we noticed the different cloud components consuming energy values are: CPU-130W (43%), Memory – 36W (12%), Disks-12W (4%), Peripheral-50W (17%), MotherBoard-25W (8%) and others – 48W (16%).

Green Peace International organization projected "ICT electricity consumption and Carbon Emissions by 2020" survey report (Green Peace International article, 2010), specified that both the Electricity consumption and Carbon Emissions will record the annual growth rate between 9 - 9.6%. They outlined the three key factors about the health of present clouds are: i) Clouds are expanding but not helping the economic growth of provider as expected, ii) highly concentrating on energy efficient cloud data centers design and iii) Popular cloud providers are constructing the extreme big data centers to tackle the competitors. In other side, this green peace article is shooting some key questions to the data center owners to support the green IT are: High Energy consumptions, Carbon emissions, Energy production sources (wind, hydraulic, coal, nuclear etc.) and efficient resource management etc. After the entire analysis on green cloud computing, we notified that the important four pillars of green clouds are energy efficiency, scalable resource management, low operating costs and environment friendliness.

3. Green Cloud Computing and its Current Trends

Green Cloud Computing is a win-win model between the cloud service provider and the environment. Green cloud not only beneficial to the environment, it also increases the profits of service provider by utilizing the resources efficiently. By insisting some management policies and characteristics in the existed cloud environment, we can make them as green certified clouds. The major characteristics of green cloud are energy efficiency, virtualization, multi-tenancy, consolidation, recycling and eco-friendliness. In this section, each green cloud character related basic definitions, implementation process, detailed information and the current trends in that area will be discussed

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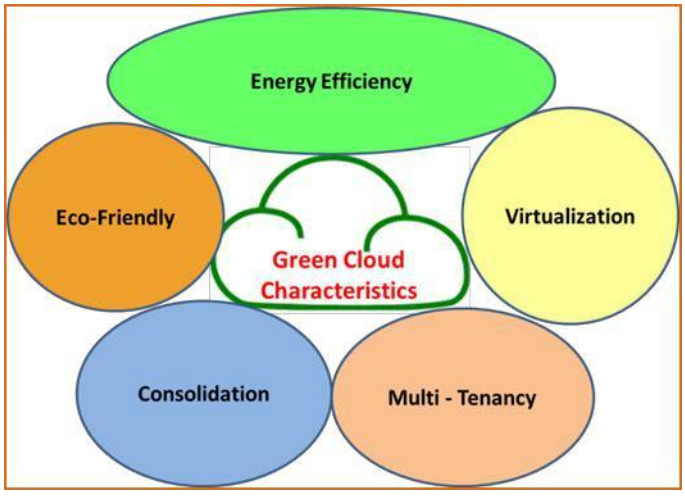

Fig. 3- Essential Characteristics of Green Cloud Computing

3.1 Energy Efficiency

The term energy efficiency is a basic building block of green cloud computing, which plays a vital role in construction of eco-friendly green clouds. Energy efficiency in cloud means, deploying the efficient power management techniques to reduce the power consumption at each cloud object (servers, data centers, disks, routers, processors etc.) level. Anton Beloglazov published a survey on energy efficient data centers and the cloud computation systems (Anton Beloglazov, Rajkumar Buyya, Young Choon Lee & Albert Zomaya 2011). In this survey they described the power consumption sources, power consumption modelling, static and dynamic power consumption methods and high power consumption problems in detail. Along with this, they discussed about the taxonomy of power management at hardware level, operating systems level, virtualization level and data center level, which are the main power consuming modules of cloud computing architecture. Static power management system supplies the same voltage of power in high utilization requirements and in low utilization requirements, and turn-on all the associated cloud resources without knowing the need of them in processing.

To avoid the unnecessary use of huge energy in cloud environment, recent researches (L. Benini, A. Bogliolo & G.D. Micheli, 2000 and D. Kliazovich & P. Bouvry, 2010) were proposed the dynamic power management (DPM) system. This system starts only the required cloud resources at beginning, estimates the power needs and supplies the adequate power voltage based on demand. If any cloud resource is supplied with the exceeded power (voltage), will be identified and corrected immediately using the dynamic power management techniques. This is called dynamic power optimization process. In section-2 also we have had a wide discussion on the energy efficiency topic and the contributions of former research scholars on it.

Dynamic Power Management (DPM), working on power utilization monitoring tools, design of power utilization simulators, Decision making algorithms design in DPM, component level power management (resource power optimization) and creation of mixed work environments are the observed current trends in this area.

3.2 Virtualization

Virtualization concept is designed to run several logical (virtual) computers on a single physical computer (hardware device) using the abstraction process. As we know that the concept virtualization (Flavio Lombardi & Roberto Di Pietro, 2011) allows the creation of multiple virtual machines to execute couple of tasks simultaneously. Hypervisor is the system software, works like as an operating system (abstraction layer) for virtual machines and coordinates with the underlying hardware components according to the virtual machine given instructions. Virtualization is not a new concept in IT, it was already implemented with our grand old Main Frames which are belongs to second generation computing devices.

Generally the cloud systems are designed with the high end configuration components like RAM's, Processors, Disks, Routers, and Switches etc. Traditional (sequential) processing methods will allocate the entire resource set to the running task(s) before they begin. The allocated resources of a task cannot be exchanged with any other running tasks. In this way the allocated resources are underutilized, blocked with some tasks, and the execution takes more time for completion. To overcome the sequential processing lilmitaions, hypervisor based VM's are designed later to run multiple jobs in parallel on same machine with resource sharing facilities. Sabahi's research paper on cloud virtualization explored different ways in creating the virtual machines (Farzad Sabahi, 2012) are: operating system based virtualizations, Application based virtualization and hypervisor based virtualization. He discussed about the privacy and security of VM's along with design of VM activity monitoring systems (VSEM, VREM). Jayabalan Subramanian (an Indian tech savvy) article (from netmagicsolutions) on cloud virtualization assumed that, cloud virtualization helps in utilizing the available resources at high rate and reduces the amount of time requires in performing a unified task, which indirectly cause to save the huge power in cloud life time. Vincent Motochi (Vincent Motochi, Samuel Barasa, Patrick Owoche & Franklin Wabwoba, 2017) et al shared their experimental analysis on cloud virtualization, to represent how the physical computer hardware reduced its power consumption using the virtualization techniques. He observed that the hyper vision selection process impact on power consumption values and launching the optimal number of virtual machines based on work load also helps in reducing the consumption at considerable rate.

Extracting High performance from resources, reducing the frequent investments on infrastructure and efficient resource utilization are the main advantages of virtualization. High speed processing, low power consumption, high-end resource utilization and cost savings are the achievements of virtualization, helps in designing the green clouds a lot. Dynamic work load balancing with VM's, Resource sharing across VM's, design of secured VM's and energy optimization techniques for virtualization are the trending activities of green clouds.

3.3 Multi Tenancy

Multi-Tenancy means an instance of cloud is servicing to multiple tenants of same category, to avoid the additional investments (creating a new cloud instance for each tenant) and utilizing the available resources efficiently. Most of the times, multi tenancy became as a controversial topic in news on cloud, due to some privacy and security issues (R. Ashalatha & J. Agarkhed, 2016) involved in its implementation. NIST (Peter Mell and Tim Grance, 2011) recognized the multi-tenancy as a main characteristic of green cloud because it helps widely to save the resources by hosting multiple tenants with one cloud instance. Cloud Security Alliance (CSA) also defined the multi-tenancy (CSA guide.v3.0) as an important corner pillar of green cloud.

Most of the times the concept multi tenancy is hard to understand by the listeners and beginners of the cloud, because it is implemented at two layers of cloud are SaaS and PaaS. At SaaS level the deployed application resources are shared among multiple tenants, i.e. SaaS contained the line-of-business category applications like SalesForce CRM, which is a single instance but offering its services to several organizations. Each customer is belongs to a separate organization but all customers are storing their data in same database tables offered by the CRM application. At PaaS level the term multi tenancy means, implementing the resource sharing process with cloud infrastructure hardware (Processor, Disk, RAM etc.) and software (virtual machines) across multiple clients to reduce the processing cost and to optimize the resource utilization. Mayang Zou et al (M. Zou, J. He & Q. Wu, 2016) explained the way, how to implement the access controls in multi-tenant cloud environment to handle the security issues while sharing the resources among different users. From the thorough analysis on cloud multi-tenancy process my research noticed that, multi-tenancy acquires more profits to the cloud service provider by servicing the multiple applications with single cloud instance. But most of the service consumers fear to participate in this multi-tenancy environment due to the privacy and security phobias. In order to accept by the cloud service consumers, the multi-tenancy has the responsibility to prove it as a secured environment for data storing and processing. Secured Multi-Tenancy development, Multi Tenancy Optimizations, Privacy preserved secure access to multi-tenancy clouds are the trending developments in this green cloud research area.

3.4 Consolidation

In Green Cloud Computing the concept consolidation means "the process of deploying different data centers related data processing applications on a single server with virtualization technology". This is the main sub task derived from virtualization and it is committed to implement the process level load balancing, better utilization of virtual systems and reducing the power consumption also. Anton Beloglazov et al (Anton Beloglazov & Rajkumar Buyya, 2012) thoroughly discussed about the need of consolidation, the procedure of dynamic consolidation of virtual machines and the advantages in detail. They explained about how to consolidate a single physical server with multiple virtual machines (one - many approach), and multiple physical servers with multiple machines (many - many approach). They proposed Online deterministic and non-deterministic algorithms to explain the process of VM's migration in cloud. In another research paper (Anton Beloglazov & Rajkumar Buyya, 2010) they proposed a threshold based approach for IaaS platform, to perform the VM's consolidation to balance the load efficiently and to avoid the resource underutilization problems. Apart from their former approaches based on threshold value, they also introduced the determination of threshold value dynamically, based on the present VM's need and their historic usage statistics.

Scholar Hosseini raised the live problems while he is doing the virtual machines consolidation process (Mirsaeid Shirvani, Amir Rahmani & Amir Sahafi, 2018). The consolidation process is resource incentive and expects the intelligence support to reduce the server down time to a minimum. To overcome the consolidation process live problems limitations, he proposed DVFS (Dynamic Voltage Frequency Scaling) based virtual machines consolidation technique, to save the energy by running the servers at different voltage frequencies. Dynamic consolidation, Threshold based consolidation, optimization of consolidation process are the present trending topics in green cloud virtual machine consolidation.

3.5 Eco-Friendliness

Economy and environment both are equal important aspects for the secured life style management of all human beings. But in reality the growth in economy spoils the environment, whereas the environment restrictions become the hurdles to economy growth. Green Computing proposed eco-friendliness bridges the gap between economy and environment using the cross cutting technologies. The term green cloud computing implies that the green clouds are environment friendly clouds, which are especially designed to minimize the environment spoiling activities (in the name of development) and ensures the non-disturbance to ecology elements. In this paper, we mostly discussed about the energy efficiency in all the way, because if we save the power means we reduced the need of power production, which helps in regulating the dioxide omissions to environment. Today energy sector is highly depending on Coal-based power generation and Nuclear-reactors based power generation systems, which releases the harmful monoxides to the environment to fulfil our energy needs.

Green Peace international organization published an article (Green Peace International article, 2010) to explain that, how the cloud computing and its elements are effecting the environment with detailed statistics and forecasts. They intimated that China and India are in front of facing the effects of carbon foot prints, because of the ICT (Information and Communication Technology) industry is recording high growth rate in both countries. They presented the total cloud consumed electricity in 2007 and forecasted the electricity consumption by 2020. Their statistics provides the information (presented in table.1) about how much carbon ($MtCO_2$) released to the environment to produce the enough electricity for cloud objects consumption.

Nitin Singh Chauhan and Ashutosh Saxena from Infosys organization wrote an article (Nitin Singh Chauhan and Ashutosh Saxena, 2013), on how to develop the energy efficient software applications. They expected that, along with the energy efficient cloud environment, the executing software application should be aware about the energy efficiency. They thoroughly examined the SDLC process of software development and identified the considerable areas of software applications to design them as environment friendly. Designing of Carbon emission directories and green cloud policies are the trending aspects in Eco-Friendliness area of green cloud computing.

Table 1 - Global statistics on total cloud energy consumption

	Electricity Consumed in 2007 (Billion KWH)	Electricity Consumption forecasted for 2020 (Billion KWH)	Electricity relevant Carbon Omissions by 2020 (MtCO2e)
Data Centers	330	1012.02	533
Telecom	293	951.72	501
Total Cloud	**623**	**1963.74**	**1034**

4. Green Cloud Future Challenges

Energy Efficiency: As the today clouds are designing with the multi-core CPU's, there is a need of designing the power optimization and management techniques to support the power management with multi-core CPU's. Another huge power consuming part of cloud is the data center, which is a collection of data storage components and data management software. An efficient power consumption monitoring system, dynamic power management system and intelligent power supply decision making systems are the research challenges in this area. By considering the today pace of IT, we need a comprehensive and intelligent mechanism to tackle with the entire cloud architecture level energy optimization issues.

Virtualization: Many former researches were widely concentrated on designing of the efficient cloud virtualization process, but the virtualization is still suffering from some high-end optimization relevant limitations. Designing the novel methodologies with the state-of-the-art technologies to optimize the entire lifecycle of virtualization process is an important research challenge. Automated optimal VM's creation with substantial resources and dynamic resource allocation & sharing facilities without affecting the cloud performance are the other considerable research challenges in virtualization. **Multi-Tenancy:** Although this an essential character of green cloud, at present multi tenancy is suffering from the privacy and security concerns. Designing the secured multi-tenant architectures and privacy-preserved secured access to multi-tenant modules are the considerable future research challenges.

Consolidation: Design of intelligence support in VM's consolidation, Multi aspect based threshold value calculation, leveraging the key resources and server downtime management became the future research challenges in this area.

Eco-Friendliness: This area mainly concentrates on environment based tools design i.e. carbon emission calculator tools to measure the effect of the cloud on nature. Need to design of a comprehensive framework to certify the clouds with ranking, based on multiple aspects of Green Cloud Computing.

5. Conclusion

As part of our research analysis on green cloud computing, in this paper we presented the literature review on green cloud computing. At glance we briefly explored the concept cloud computing and the need of designing the green clouds. Literature review presented the former scholars conducted researches on green clouds, their research identified limitations and proposed solutions. We presented the green cloud computing architecture with respective modules in detail. This paper mainly focused on exploring the notable characteristics of green cloud computing with past research discussions, present trends and future research challenges. This paper is designed by authors as a minified guide to green cloud research scholars to understand about the green cloud computing characteristics, its current trends and future research challenges.

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