

GREEN COMPUTING: AN EMERGING ENERGY SAVING TECHNOLOGY

Iswarya,

B.Sc (Computer Technology),
Department of Computer Science,
Sri Krishna Adithya College Of Arts and Science,
Coimbatore-641042 , Tamil Nadu,India.

M.Sowmiya,

B.Sc (Computer Technology),
Department of Computer Science,
Sri Krishna Adithya College Of Arts and Science,
Coimbatore-641042 , Tamil Nadu,India.

T.Yasotha,

B.Sc (Computer Technology),
Department of Computer Science,
Sri Krishna Adithya College Of Arts and Science,
Coimbatore-641042 , Tamil Nadu,India.

Abstract: Currently computers are not only used in offices but also used at home. As the usage of computers are increasing day by day, the energy consumption is growing rapidly which in turns increase the carbon content in atmosphere. Many organizations are working towards reducing the carbon footprint of their data centers; i.e. reducing their power consumption. Energy crisis led a way to green computing and green computing needs an efficient redesign of algorithms and mechanisms to meet the desired energy efficiency .Green Computing takes responsibility of eco-friendly use of computer and their resources. Green registering, likewise called green innovation is the earth maintainable utilization of PCs and related assets like - screens, printer, stockpiling gadgets, systems administration and correspondence frameworks - productively and viably with insignificant or no effect on the earth .In the present study the Green Technology concentrate to make this globe sustainable for the upcoming years. It includes the implementation of energy-efficient CPU, Servers and Peripherals as well as reduced resource consumption and proper disposal of electronic waste .The technical solution are proposed to substitute the traditional high-cost, pollution prone strategies, like Green Solutions(GS). The goal of green computing is to lower down the use of hazardous materials, maximize energy efficiency and popularize biodegradability or recyclability of out-dated products and factory waste. The main focus of this paper is to save the energy and make environment green by providing some new techniques.

Keywords: *Energy consumption, carbon footprint, Eco-friendly, E-waste, Green solution, Biodegradability.*

I.INTRODUCTION

Green Computing is the emerging technology which is responsible for the manufacturing and use of computer devices by consuming less carbon. Many computers are produced from many hazardous materials like cadmium, mercury and other toxic substances.Green computing or green IT concept has been used since 1992 with the commencement of the Energy Star program, this provided a voluntary label awarded to computing products which offered maximum efficiency while consuming minimum energy. The rating was awarded to refrigerators, television, monitors, air conditioners, and other household devices. Soon after that, the Green computing term where used to cover the computer related products such as, USBs, printers, monitors, communication systems, servers and network systems. Green processing whose objectives are to decrease the utilization of risky materials, expand vitality productivity amid the item's lifetime, and advance the recyclability or biodegradability of outdated items and industrial facility waste. Numerous associations are beginning to wipe out underutilized servers, which bring about lower vitality use. The U.S. central government has set a base 10% diminishment focus for server farm vitality use by 2011. With the guide of a so called ultra efficient evaporative cooling innovation, Google Inc. has possessed the capacity to lessen its vitality utilization to half of that of

the business normal. The term Green is strongly coupled with environment. So when we talk about Green Computing, then it is quite obvious that we are finding some solutions ,rather than strategies to build software products efficiently with minimum impact on environment .Developing a software product is not only bound to writing its core code, but also it includes several phases starting from planning to maintenance. If we want to build energy efficient green software, we have to make the whole process Green. The modern IT and Electronics Industry and here an attempt is made to analyze different green strategies that is applicable in this particular area. In order to make this green movement a big success, governments need to take some initiatives such as use of electronic documents in governments sectors rather using paper documents, because all we know paper production industry is totally based on forest removal program, this could be dangerous for environment. Moreover the maintenance of paper documents is a highly tedious job and security issue is also a matter.

Green computing can also develop solutions that offer benefits by "Aligning all IT processes and practices with the core principles of sustainability, which are to reduce, reuse, and recycle; and finding innovative ways to use IT in business processes to deliver sustainability benefits across the enterprise and beyond". The goals of green computing

are quite similar to green chemistry which are to reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability or biodegradability of non-operational products and factory waste. Green technology comprises of the study of advanced materials to be used in everyday life and the study of new generation techniques. The main topic of concern in green technology is to reduce the environmental impact of industrial processes along with the growth in population resulting in innovative technologies. Basically, the efficient use of computers and computing is what green computing is all about. This paper discusses about the need for green computing and its implementations.

II. POWER CONSUMPTION OF DATA CENTERS

As the enterprise grows, along with becoming more complex, these systems also grow in size and require the addition of new physical infrastructure. This causes the data center to grow in size. The complex nature of today's enterprise is reflected in the data center. As the enterprise grows, it is constantly adapting to changes in the environment. The acquisition of new companies and merging of IT systems is one example of change the enterprise faces. Another reason for change can be the adoption of new technologies. These changes over time, lead to a heterogeneous data center, which grew in an ad hoc manner, or sometimes in a more systematic manner. Either way, it leads to a very complex system where different systems interoperate with each other in a very knotty configuration to produce the desired service.

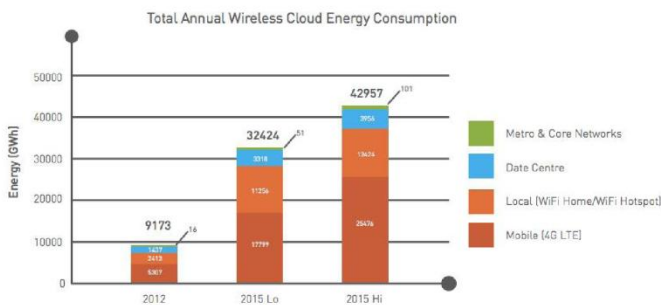


Figure 1: Power consumption of data centers

Data center facilities are considered to be huge consumers of energy, according to The U.S Department of Energy, the data center facilities are responsible of consuming 1.5% of the world's total energy use in 2010, also explained that data center consume up to 100 to 200 times more energy than standard office buildings. An estimated 91 Terawatt-hours (TWh) of electricity were datacenters consumption in U.S 2013, which is equivalent to the 34 large coal-fired (500-megawatt) power plants output for one year. By 2020, data center electricity consumption in U.S. is expected to increase to approximately 140TWh annually, which is equal to the annual output of 50 power plants, producing nearly 100 million metric tons of carbon pollution per year. As a result, costing U.S companies \$13 billion annually in electricity bills. Data centers were consumed about 1.3% of the total global electricity in 2010, or about 200 TWh. Further more, by 2025 it is expected that will increase to

1,400 TWh, which will be roughly 6% of the total global electricity consumption.

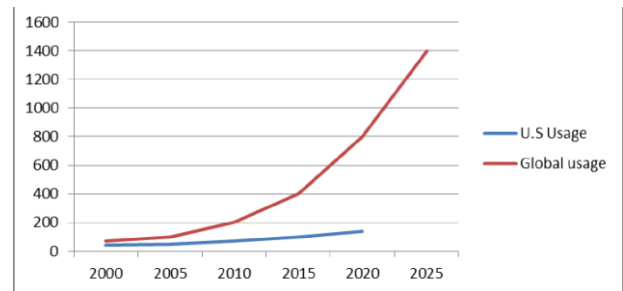


Figure 2 : Projection of Data centres Electricity Use

2.1 Data center scenario

The data center consists of a huge collection of servers, or physical machines, which have to be provided with power and cooling. The lowest block represents the data center. The four blocks on top of the data center represent four physical machines. Now, if we consider the data center environment to be consolidated and virtualized, then every physical machine will contain one or more virtual machines. If there is no virtualization, then we can treat the machine as if it is housing a single virtual machine, as can be seen in the figure – the backward right side physical machine does not have a hypervisor installed on it – it can thus run only one operating system instance, but it can still run multiple applications. Every virtual machine runs at least one application, and these applications service transactions, which are incoming requests. The requests are shown as black dots in the figure. We want to be able to trace this business value down to the level of resource allocation and power consumption and make more informed decisions when allocating virtual machines to physical ones, or deciding which applications go together on a single physical server.

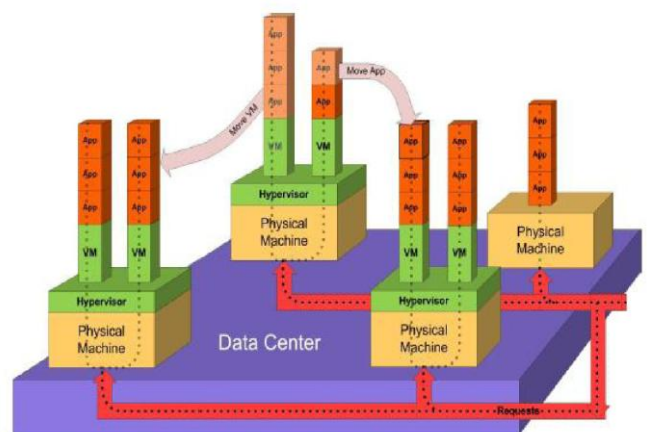


Figure 3 :Data center scenario

2.2 Need for a combined approach of it and cooling:

The two key factors listed below, make the use of static measures alone insufficient for managing power in the data center. Accordingly, the thesis proposes that a Sense and Respond (SaR) architecture is necessary for optimizing power use.

First, power consumption in modern data centers varies widely, even over short periods of time. Two major consumers of power in data centers are IT and cooling [9]. Without even considering the power used by the cooling infrastructure, the dynamic variation due to IT power fluctuations is significant. [10] reports a range of variation between 45% and 106% for typical enterprise class servers. Second, although current servers use relatively less power at idle than previous generations of hardware, every server consumes some power at idle, while at the same time it does no useful IT work. As can be seen from the range of power variation cited above, even modern hardware typically consumes at least 50% of its peak power consumption even at idle. For this reason, significantly reducing server idle time, in order to increase server utilization as much as possible, has become critical to minimizing power use while still maintaining required performance levels.

2.3 Data center sustainability improvements :

Previously in this report, some tactical actions were described for increase data center efficiency, additionally, cloud green computing can provide best practices to make data centers operation green. To build environmental data center, a number of top practices in key areas has been suggested for enhancing sustainability:

- Using renewable sources of energy such as, fuel cells, solar energy generation, cogeneration and wind power generation.
- Also there are new Cooling methods which have a great advantages over traditional ways for instances, nano-fluid cooling systems, free cooling, liquid cooling, and in-server, in-rack and in-row cooling which are been used by corporations like SprayCool, spot cooling, using cable grommets to decrease cool air leaks.
- Using new Building design for example, optimizing floor layout, heat insulation, and recycling water.
- ICT platform, dedicated racks & servers, middleware-facility linkage and virtualization technologies.
- Utilizing the latest power efficient IT equipment such as, servers and processors .

III ENERGY SAVING TECHNIQUES AND STRATEGIES

The consumption of energy and the performance of the system were influenced by many factors like hardware, software, network etc. What follow will present energy saving strategies for cloud computing data centers in the following three aspects: energy saving solutions for Servers, energy saving solutions for Network, and energy saving solutions for mixed Servers and Network. As already mentioned in this section, energy saving using renewable energy source is considered as a new area for saving energy in this paper.

3.1. Energy Saving Techniques For Servers:

Liu et al. [13] demonstrated that the average load of data center is 30% while Servers are the most energy consumers in data centers. Servers are idle most often, according to low load of data centers. Chen et al. [14] stated in a paper that an idle server for keeping memory, disks, and I/O resources in running mode may use up almost 2/3 of the peak load. It is therefore concluded that an idle server in a data center consumes a considerable amount of energy and wastes more energy comparing with other parts of data centers. The most important energy saving approaches for servers include:

- Server Virtualization
- Dynamic Power Management
- Dynamic Voltage/ Frequency scaling

Virtualization is a prominent technique for reducing energy consumption in servers. It refers to making more than one Virtual Machine (VM) on a server. Using this technique decreases the number of hardware in use, improves the utilization of resources and reduces hardware and operating expenditure. Server virtualization also allows consolidation of server workloads. The *Dynamic Voltage/Frequency scaling* approach sets the CPU power due to the presented load. By using this technique the power consumption will reduced, once CPU load is low. This technique relies on this fact that switching power in a chip reduce relatively to $V^2 * f$, while V indicates voltage, and f indicates switching frequency [12]. Moreover, reducing voltage needs frequency downshift. It represents cubic relation from f in the CPU energy usage. The following formula shows the power consumption of a server:

$$P = P_{fixed} + P_f * f^3 (1)$$

In the above formula P_{fixed} indicates the energy usage that is not measured by operating frequency f and P_f indicates the energy usage of CPU that is relying on frequency.

3.2 Energy Saving Solutions For Network

Network infrastructure is the next main energy consumer in data centers. Around 30% of the entire energy usage which utilized for computation is consumed by data center network. Network in Data Centers includes switches and links. Chabarek et al. [17] expressed in a paper that the utilization of a link is not directly balanced with its power consumption. The authors stated that power consumption depends on capacity of the link instead of its utilization.. The four following solutions are existed for saving energy in data center networks:

- Adaptive Link Rate (ALR)
- Virtual Network Embedding (VNE)
- Sleep mode
- Green routing

Adaptive Link Rate technique is extensively considered on wired networks [18]. However, it has not been used on data center networks yet. This approach is based on the idea that energy usage of a link may be decreased its data rate, while traffic load of network links are low in most situations. In such cases, Adaptive Link Rate decreases link energy usage by dynamically setting link data rate to its utilization, while *sleep mode* method decreases energy usage through switching off network resources or placing them to sleep mode. Moreover, other active network resources

should meet QoS requirements. *Virtual network embedding* is the next approach which is useful for reducing energy consumption of network [19]. VNE is mostly useful while the network traffic is low. The aims of network virtualization is to use embedding algorithms to assign virtual network resources on a fewer number of physical infrastructure with an optimal approach [20]. The idle network resources could be switched off or put into sleep mode. Recently, *Energy aware routing* or *green routing* or decreasing energy usage in data center network is studied [21]. The main idea of Energy aware routing is to deliver routing service to less number of network resources to reduce energy usage, while sustaining network performance.

IV. CARBON FOOTPRINT AND IMPLEMENTATIONS OF GREEN COMPUTING TECHNIQUES

An increase in the concentration of the main greenhouse gases — carbon dioxide, methane, nitrous oxide, and fluorocarbons — is believed to be responsible for Earth's increasing temperature, which could lead to severe floods and droughts, rising sea levels, and other environmental effects, affecting both life and the world's economy. After the 1997 Kyoto Protocol for the United Nations Framework Convention on Climate Change, the world has finally taken the first step in reducing emissions.

- (1) Offsetting carbon dioxide can be achieved in different ways. One way is to plant trees that absorb CO₂ as they grow, in the region in which the processors were purchased.
- (2) Wetlands also provide a great service in sequestering some of the carbon dioxide emitted into the atmosphere. Although they make up only 4 to 6 percent of the Earth's landmass, wetlands are capable of absorbing 20 to 25 percent of the atmospheric carbon dioxide.
- (3) Solar computing is an effective technique to utilize green computing technique
- (4) Green-computing's initiative is the development of energy-efficient platforms for low-power, small-form-factor (SFF) computing devices. This is done by the application of Quiet Computing techniques.
- (5) One should reduce the paper consumption by recycling paper regularly, using both sides of the paper, using smaller fonts and margins, and selectively printing required pages and use services like emailing and electronic archiving to minimize paper wastage.
- (6) Turn on power management features during shorter periods of inactivity. Power management allows monitors and computers to enter low-power states when sitting idle. Turn off the computer when the period of inactivity is more.
- (7) Organic light-emitting diodes should be used instead of the regular monitors.
- (8) The manufacturing of disks and boxes needed for video games takes up a lot of resources. Video game manufacturers can offer their games online for download, leading to reduction in e-waste. This move can cut down on the transportation/shipping cost.
- (9) Data centers can potentially improve their energy and space efficiency through techniques such as storage consolidation and virtualization

(10) Undervolting is a process in which both the amount of heat and electricity consumed is managed manually by the user by adjusting voltage supplied to the user. SpeedStep technology can also be put to practice to automatically manage the power consumption of a computer.

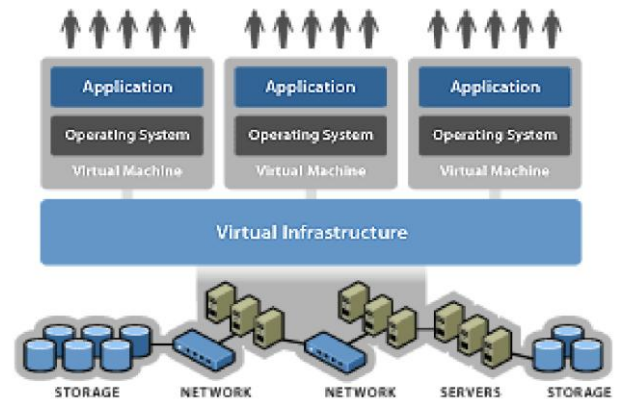


Figure 4 : computer virtualization

- **Blackle:** Blackle is a web search tool website fuelled by Google Search. Blackle appeared taking into account the idea that when a PC screen is white, exhibiting an unfilled word or the Google home, your PC expends 74W. At the point when the screen is dark it devours just 59W. Based on this hypothesis if everybody changed from Google to Blackle, mother earth would save 750MW every year. This was a better than average usage of Green Computing. The guideline behind Blackle depends on the way that the showcase of diverse hues expends distinctive measures of vitality on PC screens.
- **Fit-PC:** A little PC that draws just 5w: Fit-PC is the extent of a soft cover and totally noiseless, yet sufficiently fit to run Windows XP or Linux. fit-PC is intended to fit where a standard PC is excessively cumbersome, boisterous and power hungry. In the event that you ever longed for a PC to be conservative, tranquil and green then fit-PC is the ideal fit for you. Fit-PC draws only 5 Watts, devouring in a day less power than a customary PC expends in 60 minutes. You can leave fit-PC to work day in and day out without making an imprint in your electric bill.
- **Zonbu Computer:** The Zonbu is another, extremely vitality effective PC. The Zonbu devours only 33% of the force of a common light. The gadget runs the Linux working framework utilizing a 1.2 gigahertz processor and 512 meg of RAM. It likewise contains no moving parts, and evens contain a fan. You can get one for as meager as US\$99, however it requires you to agree to a two-year membership Dell is a good example of a company with a green image, known for its free worldwide **product-recycling program**.

V. GREEN SOLUTIONS

1) Use of Ultra-Low Voltage VLSI circuits:

The need for green computing and nearly-minimum energy operation is continuously pushing VLSI circuits and systems

toward lower voltages. From this perspective, sub-threshold and near-threshold operation have become very attractive under low to moderately high performance targets. But this concept is associated with some other questions too, such as ultra-low voltage operation poses many challenges related to (i) Reliable operation despite of variations and transient errors, (ii) Reduction of the energy/performance penalty due to uncertainty and design margining (iii) Energy scalability and adaptation to a wide range of operating conditions, (iv) Efficient modeling and design exploration, (v) Reduction of cost associated with design.

2) Use of proper software development model:

Choice of proper software development model is strongly associated with green computing. In many IT industries, no specific model is used actually to develop a software. Though they develop quite good software, but some questions arise due to the choice of improper software development model and its impact on the environment. All we know there are some very primitive type of software development models are available like Iterative Waterfall Model, Spiral Model, Evolutionary Model, Prototype Model etc. But we just cannot use any of these for any project in a random manner. All these models are not well suited for all software development both in terms of technical aspects and environmental issues. We can take another example also, in some projects where the client's need is mono-changing or the developer's idea is not clear, Spiral Model or Prototype Model is good solution instead of choosing Waterfall Model.

3) Elimination of Recursion:

In terms of green computing, recursion is not a good practice in programming. All we know that when we use recursion in our programs, then the compiler need to maintain internal stacks to execute programs. Sometimes this technique takes a lot of space and time causing degradation of performance as well as extra energy consumption. Some compiler converts recursion into iteration.

4) Resource Hibernation and Sleep Mode:

Hibernation is the process of using low power mode. An idle resource can be kept in hibernate state but switching to and from this state can be wastage of precious resources and time. This mode saves energy and protects your work by copying system data to a reserved area on your hard drive and then completely turning off your computer. Another important term is —Sleep Model. It is also known as Standby Mode. Sleep or Standby mode conserves energy by cutting off power to your display, hard drives and peripherals. After a pre-set period of inactivity, computer switches to a low power state.

5) Dynamic Power Management:

Power consumption in Complementary Metal-Oxide Semiconductors (CMOS) is categorized into static and dynamic. Power consumption is dynamic when circuit is in operating state and no power leakage occurs. Whereas power consumption is static, when circuit will not be in running form but it is still powered. Dynamic power management system sets the power of its hardware in true

time without degradation in performance to decrease probable power waste. Dynamic Voltage and Frequency Scaling (DVFS), Dynamic Process and Temperature (DPT) compensation and idle time prediction are some power aware software that can drive hardware power saving mechanisms. Use of those software in some specific fields like Green Compiler design and Real time system development can optimize the energy consumption in very brilliant manner.

6) Use of energy aware data structure:

Data structures have significant effect in execution of a program and energy conservation as efficient data structure is more energy conservative. Research shows that merge sort consumes less energy with array data structure whereas it consumes more energy in the case of link list data structure. Furthermore, compilation of various data structures APIs such as linked list, arrays etc. with some energy conservative compiler make these data structure energy aware and use of them in program may leads energy conservation.

7) Distributed Green Compiler:

Distributed Green Compiler formulates an energy conservative executable by applying several green techniques to reshape source code during intermediate code conversion. A classic green compiler requires more time to compile the source code for energy conservative executable. It applies green strategies in compilation hence leads to degradation of performance. Distributed Green Compiler decreases compilation time by distributing source code over a network of physical or virtual machines. However, software developer also has the option to compile program on a single machines. Compiler cannot reshape all source code in energy conservative executable, for example recursion elimination, use of register operands. Distributed Green Compiler provides green suggestions for software developers by highlighting the areas of source code, which cannot be reshaped by compiler for energy optimization during intermediate code conversion.

8) Concept of Energy Star:

One of the first manifestations of the green computing movement was the launch of energy star program back in 1992 by the Environmental Protection Agency and the Department of Energy. Energy Star served as a kind of voluntary label awarded to computing products that succeeded in minimizing use of energy while maximizing efficiency. Energy Star applied to products like computer monitors, television sets and temperature control devices like refrigerators, air conditioners, and similar items. Device carrying the Energy Star service mark, such as computer products and peripherals, kitchen appliances, building or other products generally use 20-30% less energy than required by federal standards. In the United States the Energy Star label is also known as the Energy Guide appliance label for qualifying products. Energy Star specifications differ with each item, and are set by either the Environmental Protection Agency or the Department of Energy. In November 2008, television specifications were

improved to limit on-mode power use, in addition to standby power which is limited by the current specifications.

VI. CONCLUSION

Green computing represents a responsible way to address the issue of global warming. By adopting green computing practices, business leaders can contribute positively to environmental stewardship—and protect the environment while also reducing energy and paper costs. To make the computer society completely green, we should adopt green computing. When computer components are not in our use then the components must be donated to those people who may not have those components. Instead of discarding computers, upgrade their parts in order to make them new. Go green is a concept which is used in few organizations but if everyone use its components then it could be beneficial for everyone. The benefits of green computing are clear. As the number of PCs approaches 2 Billion by 2015, the potential savings related to energy use, CO₂ emissions and e-waste are undeniable. As a result, businesses and consumers alike have started to embrace environmentally sustainable products that offer low carbon solutions that can not only reduce their global greenhouse gas (GHG) emissions, but can do so by more efficient energy consumption and lower costs. An effective and efficient use of computing resources in cloud can help in achieving Green Cloud Computing. We need a system that takes power consumption and cooling power into account, in addition to server load, while allocating virtual machines to servers. However, such a complex system needs a good management system to be effective. So Green Computing is the emerging technology which is more over like aid and need to sustain the eco friendly environment. we can all provide a better future for next generation. Let's Go green and Save our motherland.

VII. REFERENCES

- [1]. Green Computing - a new Horizon of Energy Efficiency and Electronic waste minimization: a Global Perspective, Shalabh Agarwal and Asoke Nath : Proceedings of IEEE CSNT-2011 held at SMVDU(Jammu) 03- 06 June 2011, Page 688-693(2011).
- [2]. Green Computing Endeavor in Higher Educational Institutes – a noble initiative towards Sustainable IT Infrastructure, Shalabh Agarwal, Archana Vimal, Saima Ghosh, Asoke Nath, Journal of Computing (USA), Vol 4, issues 5, May, ISSN-9617, Page-217-222, 2012
- [3]. Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools Copyright © Shaker Verlag 2009. ISBN: 978-3-8322-8397-1
- [4]. Gaurav Jindal, Manisha Gupta, “Green Computing, Future of Computers” in International Journal of Emerging Research in Management & Technology, December 2012, pp. 14-18.
- [5]. Tariq Rahim Soomro and Muhammad Sarwar, “Green Computing: From Current to Future Trends” in International Scholarly and Scientific Research & Innovation, Vol:6, March 2012, pp. 455-458.
- [6]. J. Chase, D. Anderson, P. Thakar, A. Vahdat, and R. Doyle. Managing energy and server resources in hosting centers. In Proceedings of the 18th Symposium on Operating Systems Principles (SOSP), 2001.
- [7]. Maria Kazandjieva, Brandon Heller, Omprakash Gnawali. *Green Enterprise Computing Data: Assumptions and Realities*
- [8]. Navdeep Kochhar, Arun Garg, 'Eco-Friendly Computing: Green Computing'
- [9]. Report to congress on server and data center energy efficiency. Technical report, U.S. Environmental Protection Agency, Energy Star Program, August 2007.
- [10]. J. Spitaels. Dynamic power variations in data centers and network rooms. American Power Conversion White Paper, 2005.
- [11]. http://en.wikipedia.org/wiki/Green_computing
- [12]. D. Kliazovich, P. Bouvry, and S. U. Khan, "GreenCloud: a packet-level simulator of energy-aware cloud computing data centers," *The Journal of Supercomputing*, vol. 62, pp. 1263-1283, 2012.
- [13]. J. Liu, F. Zhao, X. Liu, and W. He, "Challenges towards elastic power management in internet data centers," in *Distributed Computing Systems Workshops, 2009. ICDCS Workshops' 09. 29th IEEE International Conference on*, 2009, pp. 65-72.
- [14]. G. Chen, W. He, J. Liu, S. Nath, L. Rigas, L. Xiao, *et al.*, "Energy-Aware Server Provisioning and Load Dispatching for Connection-Intensive Internet Services," in *NSDI*, 2008, pp. 337-350.
- [15]. <http://www.wisegeek.com/what-is-green-computing.htm>.
- [16]. Derya C, avdar and Fatih Alagoz, "Survey of Research on Greening Data Centres" in Symposium on Selected Areas in Communications Globecom 2012
- [17]. J. Chabarek, J. Sommers, P. Barford, C. Estan, D. Tsiang, and S. Wright, "Power awareness in network design and routing," in *INFOCOM 2008. The 27th Conference on Computer Communications. IEEE*, 2008.
- [18]. C. Gunaratne, K. Christensen, B. Nordman, and S. Suen, "Reducing the energy consumption of Ethernet with adaptive link rate (ALR)," *Computers, IEEE Transactions on*, vol. 57, pp. 448-461, 2008.
- [19]. J. F. Botero, X. Hesselbach, M. Duelli, D. Schlosser, A. Fischer, and H. De Meer, "Energy efficient virtual network embedding," *Communications Letters, IEEE*, vol. 16, pp. 756-759, 2012.
- [20]. A. Fischer, J. F. Botero, M. Till Beck, H. De Meer, and X. Hesselbach, "Virtual network embedding: A survey," *Communications Surveys & Tutorials, IEEE*, vol. 15, pp. 1888- 1906, 2013.
- [21]. Y. Shang, D. Li, and M. Xu, "Energy-aware routing in data center network," in *Proceedings of the first ACM SIGCOMM workshop on Green networking*, 2010, pp. 1-8.