

Green Computing: From Current to Future Trends

Tariq Rahim Soomro and Muhammad Sarwar

Abstract—During recent years, attention in 'Green Computing' has moved research into energy-saving techniques for home computers to enterprise systems' Client and Server machines. Saving energy or reduction of carbon footprints is one of the aspects of Green Computing. The research in the direction of Green Computing is more than just saving energy and reducing carbon foot prints. This study provides a brief account of Green Computing. The emphasis of this study is on current trends in Green Computing; challenges in the field of Green Computing and the future trends of Green Computing.

Keywords—Energy consumption, e-waste recycling, Green Computing, Green IT

I. INTRODUCTION

THE term 'Green Computing' is the study and practices that covers the computing lifecycle from cradle to grave. It start from design to manufacturing to use of equipment and then safely disposing-off computers, related devices, networking and communications equipments efficiently and effectively with negligible or no impact on the environment [1]. First and most conclusive research on computing shows that Carbon Dioxide (CO₂) and other emissions are causing global climate and environmental damage. Preserving our beloved planet is a main and legitimate goal because it aims to preserve life. It has given extreme attention by researchers and professionals to minimize e-waste and use of non-toxic materials in preparation of e-equipments. Energy efficiency is increasingly important for future ICT (Information and Communication Technologies) as the cost, and availability of energy is rising day by day. The increased usage of ICT with increasing energy costs and the need to reduce greenhouse gas emissions demand for energy-efficient technologies that decrease the overall energy consumption of computation, storage and communications. The very first and most conclusive research shows that CO₂ and other emissions are causing global climate and environment a huge damage. Therefore it is the top most priority and challenge for Green Computing technologist to preserve our beloved planet. On the other hand a study by "The Climate Group" entitled Smart 2020 (<http://www.theclimategroup.org/programs/ict/>) predicts that, greenhouse gas emissions from the Internet industry will raise to approximately 1.3 Giga-tons of CO₂, and the combined impact of smart grid; smart logistics; smart buildings; and videoconferencing could reduce emissions by approximately 7.8 tons.

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In recent years focus of enterprises and technology firms has been shifted towards Green Computing rapidly. Green Computing discusses the options to support critical computing needs in sustainable manner by reducing strains on resources and environment. One of the main objectives of Green Computing is about improving computing performance and reducing the energy consumption & carbon footprints. This paper is organized as follows: next, section 2 reviews current trends in the field of Green Computing; section 3 will explore the challenges of Green Computing; section 4 will discuss the future trends towards Green Computing; and finally this study summarized the issues related to Green Computing and concludes.

II. CURRENT TRENDS

Current trends of Green Computing are towards efficient utilization of resources. Energy is considered as the main resource and the carbon footprints are considered the major threads to environment. Therefore, the emphasis is to reduce the energy utilization & carbon footprints and increase the performance of Computing. There are several areas where researchers are putting lots of efforts to achieve desired results:

A. Energy Consumption

Organizations are realizing that the source and amount of their energy consumption significantly contributes to Greenhouse Gas (GhG) emissions. In response to this finding, organizations are currently using the following equation:

$$\begin{aligned} \text{Reduced energy consumption} &= \\ \text{Reduced greenhouse gas emissions} &= \\ \text{Reduced operational costs for the data center} & \end{aligned}$$

It means adopting fewer and more energy efficient systems while refactoring application environments to make optimal use of physical resources is the best architectural model. According to Environmental Protection Agency in around 30% to 40% of personal computers are kept 'ON' after office hours and during the weekend and even around 90% of those computers are idle.

B. E-Waste Recycling

Based on the Gartner estimations over 133,000 PCs are discarded by U.S. homes and businesses every day and less than 10 percent of all electronics are currently recycled. Majority of countries around the world require electronic companies to finance and manage recycling programs for their products especially under-developed Countries. Green Computing must take the product life cycle into consideration; from production to operation to recycling. E-Waste is a manageable piece of the waste stream and recycling e-Waste is

easy to adopt. Recycling computing equipment such as lead and mercury enables to replace equipment that otherwise would have been manufactured. The reuse of such equipments allows saving energy and reducing impact on environment, which can be due to electronic wastes [2].

C. Data Center Consolidation & Optimization

Currently much of the emphasis of Green Computing area is on Data Centers, as the Data Centers are known for their energy hunger and wasteful energy consumptions. United State Department of Energy (DoE) reported in its study in 2006 that United States data centers consumed 1.5% of all electricity and their demand is increasing by 12% per year and cost \$7.4 billion per year by 2011. According to DoE's current report in July 2011 Data Centers are consuming 3% of all US electricity and this consumption will double by 2015 [3]. With the purpose of reducing energy consumption in Data Centers it is worthwhile to concentrate on following [4]:

- Information Systems – efficient and right set information systems for business needs are a key in building Green Data Centers. As per green computing best practices efficient servers, storage devices, networking equipments and power supply selection play a key role in design of information systems.
- Cooling Systems – it is suggested by the researchers that at the initial stage of design process for data center cooling systems, it is significant to consider both current and future requirements and design the cooling system in such a way so it is expandable as needs for cooling dictates.
- Standardized environment for equipment is must for Data Center Air Management and Cooling System.
- Consider initial and future loads, when designing & selecting data center electrical system equipment.

D. Virtualization

One of the main trends of Green Computing is virtualization of computer resources. Abstraction of computer resources, such as the running two or more logical computer systems on one set of physical hardware is called virtualization. Virtualization is a trend of Green computing it offers virtualization software as well as management software for virtualized environments [5]. One of the best ways to go towards green and save enough space, enough resources, and the environment is by streamlining efficiency with virtualization. This form of Green Computing will lead to Server consolidation and enhance computer security [6]. Virtualization runs fewer systems at higher levels of utilization. Virtualization allows full utilization of computer resources and benefits in:

- Reduction of total amount of hardware;
- Power off Idle Virtual Server to save resources and energy; and
- Reduction in total space, air and rent requirements ultimately reduces the cost

E. IT Products and eco-labeling

Another approach to promote Green Computing and save environment is to introduce policies all around the World, so that, companies design products to receive the eco-label [7]. There are several organizations in the world which support “eco-label” IT products. These organizations provide certificates to IT products based on factors including design for recycling, recycling system, noise energy consumption etc. [8].

III. CHALLENGES

According to researchers in the past the focus was on computing efficiency and cost associated to IT equipments and infrastructure services were considered low cost and available. Now infrastructure is becoming the bottleneck in IT environments and the reason for this shift is due to growing computing needs, energy cost and global warming. This shift is a great challenge for IT industry. Therefore now researchers are focusing on the cooling system, power and data center space. At one extreme it is the processing power that is important to business and on the other extreme it is the drive, challenge of environment friendly system, and infrastructure limitations [9]. Green Computing challenges are not only for IT equipments users but also for the IT equipments Vendors. Several major vendors have made considerable progress in this area, for example, Hewlett-Packard recently unveiled what it calls “the greenest computer ever”—the HP rp5700 desktop PC. The HP rp5700 exceeds U.S. Energy Star 4.0 standards, and has an expected life of at least five years, and 90% of its materials are recyclable [3]. Dell is speeding up its programs to reduce hazardous substances in its computers, and its new Dell OptiPlex desktops are 50% more energy-efficient than similar systems manufactured in 2005, credit goes to more energy-efficient processors, new power management features, and other related factors [3]. IBM is working on technology to develop cheaper and more efficient solar cells plus many other solutions from IBM to support sustainable IT. According to researchers of Green Computing following are few prominent challenges that Green computing is facing today [9]:

- Equipment power density / Power and cooling capacities;
- Increase in energy requirements for Data Centers and growing energy cost;
- Control on increasing requirements of heat removing equipment, which increases because of increase in total power consumption by IT equipments;
- Equipment Life cycle management – Cradle to Grave; and
- Disposal of Electronic Wastes

IV. FUTURE TRENDS

As discussed earlier the reason for shift is because of growth in computing needs, energy cost and global warming and this shift is great challenge for IT industry. The future of Green Computing is going to be based on efficiency, rather than reduction in consumption [10].

The primarily focus of Green IT is in the organization's self interest in energy cost reduction, at Data Centers and at desktops, and the result of which is the corresponding reduction in carbon generation. The secondary focus of Green IT needs to focus beyond energy use in the Data Center and the focus should be on innovation and improving alignment with overall corporate social responsibility efforts. This secondary focus will demand the development of Green Computing strategies. The idea of sustainability addresses the subject of business value creation while ensuring that long-term environmental resources are not impacted. There are few efforts, which all enterprises are supposed to take care of [2]:

A. Certifications

There are several organizations providing certificates to green technology. Vendors are based on their product quality, material, life of the product and recycling capabilities. In future such certifications together with recommendations and government regulations will put more pressure on vendors to use green technology and reduce impact on environment.

B. Cloud Computing

Cloud Computing has recently received significant attention [11], as a promising approach for delivering Information and Communication Technology services by improving the utilization of Data Center resources. In principle, cloud computing is energy-efficient technology for ICT [12] provided that it's potential for significant energy savings that have so far focused on only hardware aspects, can be fully explored with respect to system operation and networking aspects also. Cloud Computing results in better resource utilization, which is good for the sustainability movement for green technology.

C. Product Longevity

As per Gartner and Fujitsu reports on product life cycle it is obvious that the product durability and/or longevity are one of the best approaches towards achieving Green Computing objectives [13]. Long life of product will allow more utilization of products and it will put a control on unnecessary manufacturing of products. It is obvious that government regulations will push the products vendors to make more efforts to increase the product life.

D. Power Management Tools

Power management is proving to be one of the most valuable and clear-cut techniques in near future to decrease energy consumption. IT departments with focus on saving energy can decrease use with a centralized power management tool. Compiling data from Energy Star case studies for 7 deployments of 11,000 - 499,000 machines, it was found that sleep scheduling was able to save between \$10.75 and \$95 per computer per year. These deployments used a combination Windows built-in sleep function, group policies, different software systems, such as PC Power-down, EZ GPO, Tivoli systems, BigFix etc. [10].

E. Leveraging Unused Computer Resource

One of the exiting areas where Green Computing can grow is the share and use efficiently the unused resources on idle computers. Leveraging the unused computing power of modern machines to create an environmentally proficient substitute to traditional desktop computing is cost effective option. This makes it possible to reduce CO2 emissions by up to 15 tons per year per system and reduce electronic waste by up to 80% [14].

F. Data Compression

In enterprise, huge amount of data that is stored is somehow or other duplicated information. Information System backups are true example of such duplicated data. Intelligent compression techniques can be used to compress the data and eliminate duplicates help in cutting the data storage requirements.

G. Applications

Green Computing is a diverse field and due to its nature and priority from all fields of life Green Computing has applications in every sector of computing as the goal is to save the environment and ultimately the life. The current main applications of Green Computing are covering following computing sectors [15]:

- Equipment design;
- Equipment recycling;
- Data Center optimization and consolidation;
- Virtualization;
- Paper free environment;
- Application Architecture; and
- Power Management

V. CONCLUSION

Technology is not a passive observer, but it is an active contributor in achieving the goals of Green Computing. IT industry is putting efforts in all its sectors to achieve Green computing. Equipment recycling, reduction of paper usage, virtualization, cloud computing, power management, Green manufacturing are the key initiatives towards Green computing. Current challenges to achieve Green Computing are enormous and the impact is on computing performance. Efforts of Governments and Non-Government Organizations (NGOs) are also appreciate-able. Government regulations are pushing Vendors to act green; behave green; do green; go green; think green; use green and no doubt to reduce energy consumptions as well. All these efforts are still in limited areas and currently efforts are mainly to reduce energy consumption, e-Waste but the future of Green Computing will be depending on efficiency and Green products. Future work in Green Computing discipline will also rely on research work in academics since this is an emerging discipline and there is much more need to be done. There is need for more research in this discipline especially within academic sector.

REFERENCES

- [1] Prof. Riyaz A. Sheikh, Dr. U.A. Lanjewar, Green Computing- Embrace a Secure Future, International Journal of Computer Applications (0975 – 8887), volume 10-N.4, November 2010, <http://www.ijcaonline.org/volume10/number4/pxc3871984.pdf>
- [2] Robert R. Harmon, Haluk Demirkan, The Corporate Sustainability Dimensions of Service-Oriented Information Technology, Annual SRII Global Conference, March 29 2011 – April 2 2011, DOI: 10.1109/SRII.2011.116, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5958139
- [3] PatrikKorp, Green Computing – Are you ready for a personal energy meter?, Communication of the ACM, 2008, Vol 51, No. 10, DOI: 10.1145/1400181.1400186, http://www.eecs.wsu.edu/~tlu/PhD_Power_Aware_Computing/GreenComputing.pdf
- [4] Prepared by the National Renewable Energy Laboratory, Best Practices Guide for Energy-Efficient Data Center Design, FEDERAL ENERGY MANAGEMENT PROGRAM, Revised March 2011, <http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf>
- [5] Dan Kusnetzky, Virtualization and Green Computing, 17 May 2007, <http://www.zdnet.com/blog/virtualization/virtualization-and-green-computing/141>
- [6] Automation Business Technologies, Green Computing Through Virtualization, <http://automationbusinesstech.com/green-computing-virtualization-virginia>, Retrieved December 2011
- [7] Bright Hub, History of Green Computing, Its Uses, the Necessity and the Future, November 2011, <http://www.brighthub.com/environment/green-computing/articles/62742.aspx>
- [8] H. Sato, Eco-Labeling and Green Procurement Schemes for IT-Products: The Japanese Approach, <http://enviroscope.iges.or.jp/modules/envirolib/upload/1511/attach/Paper%209.pdf>, Retrieved December 2011-12-31
- [9] David Wang, Meeting Green Computing Challenges, International Symposium on High Density packaging and Microsystem Integration, 26-28 June 2007, DOI: 10.1109/HDP.2007.4283590, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4763421
- [10] Software or Hardware: The Future of Green Enterprise Computing, paper 185, http://sing.stanford.edu/cs303-sp11/papers/green_computers.pdf, Retrieved December 2011
- [11] Tariq Rahim Soomro, Hasan Wahba, Perspectives of Cloud Computing: An Overview, 14th International Business Information Management Association (IBIMA) Conference on Global Business Transformation through Innovation and Knowledge Management, Istanbul, Turkey 23-24 June 2010, <http://www.ibima.org/TR2010/papers/soo.html>
- [12] Andreas Berl, Erol Gelenbe, Marco Di Girolamo, Giovanni Giuliani, The Computer Journal, 2009, Volume 53, Issue 7, pp. 1045-1051, DOI: 10.1093/comjnl/bxp080, <http://comjnl.oxfordjournals.org/content/53/7/1045.short?rss=1>
- [13] Green computing, http://en.wikipedia.org/wiki/Green_computing, Retrieved December 2011
- [14] Useful, Useful is the Green Solution: reduce CO₂ emissions and electronic waste, 2011, <http://www2.useful.com/green-pcs>
- [15] Pirate, AuthorStream, Green Computing, <http://www.authorstream.com/Presentation/piratebhai-727374-green-computing/>, Retrieved December 2011