Green Computing: A Primer

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Abstract Green computing refers to the practice of reducing environmental footprints of technology by efficiently using computing assets. It is using computer systems in sustainable environmental way that minimizes power usage of electronic devices/systems like monitors, desktops, printers, communication gadgets, and datacenters. As computing becomes increasingly pervasive, green computing has been a major concern for businesses and governments worldwide. This paper provides a brief introduction to green computing.

Introduction

In the 21st century, the word "green" has evolved to relate to environmental issues. Behaving in an environmentally sound way will be essential to our future. The Earth may no longer be a sustainable living environment for any creature if we do no reduce the rate and amount of toxic waste [1]. High levels of carbon dioxide (CO_2) emission is dangerous and can cause health problems. As computing becomes increasingly pervasive, the energy consumption due to computing keeps increasing. Green computing is emerging as a critical information communication technology to reverse the trend. It is using computing resources in an environment friendly manner while maintaining overall computing performance.
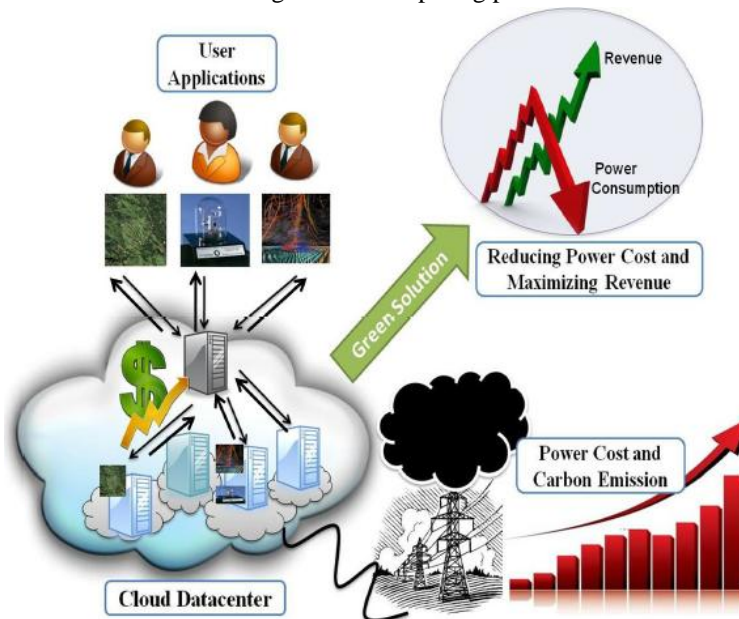

Figure 1: A typical illustration of green computing [5].

The goals of green computing (GC) are similar to those of green chemistry: reduce the use of hazardous materials and maximize energy efficiency during the product's lifetime. Green computing is the movement towards a more environmentally sustainable computing. It seeks to conserve the energy and reduce the e-waste. It is important for all classes of computing systems, from handheld mobile devices to data center facilities, which are heavy consumers of energy [2,3].

Many governmental agencies and non-profit organizations have implemented standards and regulations that encourage green computing. Some countries have launched a number of "paperless" initiatives with the aim of reducing the use of paper in offices [4]. Many companies are exploring methods and developing policies to use green technologies. Companies in the computer industry are interested in green computing because it saves energy and expenditure cost. Green computing is illustrated in Figure 1 [5].

Background

One of the biggest challenges facing the environment today is global warming due to carbon emissions. The term "green" is used to refer to environmentally sustainable activities. It means using computers in ways that **save the environment, save energy and save money. The concept of** green computing was originated in 1992 by U.S. Environment Protection Agency by launching a Energy Star rating in monitors and other electronic equipment.

To be green requires [6]: (1) improving energy efficiency by reducing carbon footprint. (2) reducing e-waste, and (3) enabling lifestyle changes that lower impact on the environment.

Green Computing may be regarded as the practice of using computing resources to achieve maximum productivity with no harmful effect to the environment. The key objectives of green computing include [7]:

- Minimizing energy expenditure
- Purchasing green energy
- Reducing the paper and other consumables used
- Minimizing equipment removal necessities
- Reducing travel requirements for employees /customers

Green computing essentially includes four key areas illustrated in Figure 2 and explained as follows [8]:

- *Green Use:* Using resources in an environmentally sound manner while reducing their energy consumption.
- *Green Design:* Designing energy efficient and environmentally sound objects and services.
- *Green Disposal:* Recycling e-waste with minimal or no impact on the environment.
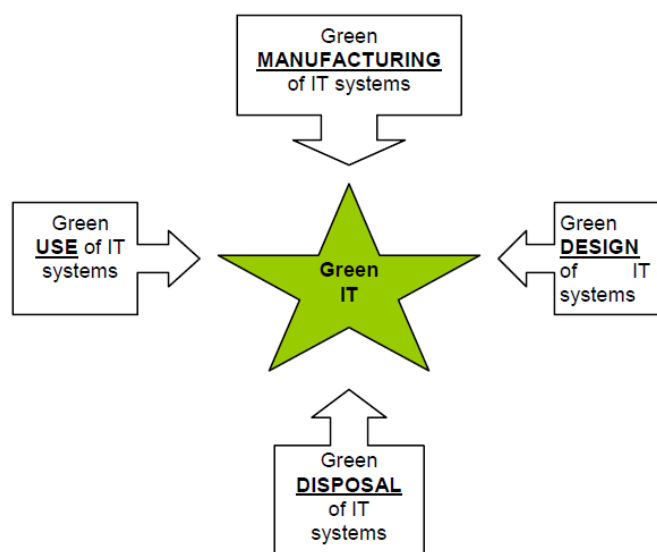- *Green Manufacturing:* Manufacturing electronic devices with minimal impact or no impact on the environment.

Figure 2: Four key areas in greeting IT/computing [8].

From this, we notice that the main objective of green computing involves the usage, designing, disposal, and manufacturing of information and communication technology (ICT) for environmental sustainability. Therefore, a green computer is one where the entire process from design, manufacture, use, and disposal involves as little environmental impact as possible.

Ways to Implement GC

There is no easy way to green computing. We must strive to minimize green house gases and waste, while increasing the effectiveness of IT, such as computers, data centers, and computer networks. A green computing activity must cover all territories: people, organizations, equipment, and networks.

1. Home Usage: The home office is an area of the house where energy is wasted and lost. Buy "energy star" labeled monitors, desktops, laptops, and printers. Turn off your PC, laptops, and other equipment or put them in "sleep" mode when not in use. Automatic switching off of the computers when they are not in use helps reduce the power consumption. E-cycle used electronic equipment. Minimize using papers through the paperless approach and reduce the use of printers.

2. E-Waste Recycling: This is recycling of e-waste such as old computers, monitors, phone, and TV. You can give them to non-profit organization instead of throwing them away. Recycling computing hardware can keep unsafe materials (such as lead, mercury) out of landfills. Proper management of e-waste is a good potential route to implementing green computing [9].

3. Energy Efficient Data Center: Data centers facilities were harmful for the environment and have been noted as heavy consumers of energy. Large amounts of energy were needed for powering servers and cooling them thereby incurring enormous carbon footprints. The U.S. Department of Energy specifies five primary areas on which to focus energy efficient data center design best practices: information technology (IT) systems, environmental conditions, air management, cooling systems, and electrical systems. It will require green cloud computing solutions to save energy and reduce operational costs and carbon emission [10].

4. Organizations: Organizations are causing increase in the carbon foot print. They should have a budget for green computing. They should have policies for printing, recycling, and IT procurement. An international consortium of computer companies, including IBM, Dell, IBM, and Sun Microsystems organized The Green Grid in 2007 to improve energy efficiency in business computing systems [11]. To encourage paperless policy, many universities charge for printing, and this makes students take some responsibility for their printing.

Benefits and Challenges

By choosing green computing hardware and software resources, we can significantly reduce carbon footprint, save money, and improve the reuse cycle. Other benefits of green computing include [12]:

- Reduce energy consumption of computing resources
- Reduce carbon emission
- Reduce harmful effects of computing resources
- Reduce computing wastes
- **Reduce operational cost**
- Save energy during idle operation
- Use eco-friendly sources of energy
- Utilizes resources such as computers, data centers, light, etc. in an environmental friendly way
- **I**mprove corporate image by meeting compliance and regulatory requirements

Green computing presents some challenges for business people, engineers, and architects. It requires that designer takes the product life cycle into consideration, from production to operation to recycling. There are *privacy and ethical issues* that arise from the recycling of the old computer. Computers gathered through recycling drives are often shipped to developing countries, where environmental standards are less strict than in Western world. Developed countries are already implementing green computing solutions, while developing countries are just at awareness stage.

Current Trends on GC

Current trends of green computing are towards efficient utilization of resources. There are various ways by which researchers are seeking to achieve desired this [13]. The most popular approaches are using virtualization and cloud computing.

A major trend of green computing is virtualization of computer resources. Virtualization provides a path toward green by offering virtualization software as well as management software. Virtualization and green solutions are both easier to implement if one has a well-understood hardware base.

Cloud computing is the latest trend in the field of green computing. It does away with the hardware servers and uses virtual servers. Thus, cloud computing is energy-efficient technology for ICT. It provides better resource utilization, which is good for the sustainability movement for green technology [14].

The use of virtualization along with that of cloud computing is playing an important role in green computing concept. Cloud virtualization involves virtualizing not just resources but also the location and ownership of the infrastructure through the use of cloud computing. It leverages the economies of scale due large numbers of organizations sharing the same infrastructure.

Conclusıon

Green computing is the practice of using computing resources efficiently. It is ecologically sustainable computing with the goal of increasing the energy efficiency during the product lifetime. By going "green" in computing, we help advance an eco-friendly and cleaner environment.

Today organizations have come to realize that going green is in their best interest and

are moving towards implementation of green computing platform. Several universities are also launching academic initiatives in this discipline [15]. In order for the whole society to consider green computing an essential part of environmental responsibility, the average citizen (including college students) must be well informed. Awareness should also be increased regarding green computing since it will have major impact in future computing.

By eliminating the environment-unfriendly aspects of computer systems, green computing can enable computer systems, computer networks, people, society, and environment to be in better harmony. For information on green computing can be found in the book by Smith [16].

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