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GREEN IT: NEED OF HOUR

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Abstract: Information Technology has influenced the corporate world, society and an entire human life remarkably. As a result of this IT infrastructure is growing rapidly. It consumes huge amount of electricity which is responsible for greenhouse gas (GHG) emissions. IT industry is creating lot of environmental problems during manufacturing, usage and disposal of computer hardware. Apart from changing global climate and weather patterns GHG emissions are creating environmental problems like floods, droughts, storms, excessive heat and other natural disasters. We can utilize the power of IT to address these environmental issues. Green IT can be seen as a savior of these environmental issues. Thus Green IT deals with study and practice of using computer systems efficiently with minimal impact on environment. This paper outlines Green IT practices, strategies, processes and policies to reduce environmental impacts of IT industry. It also details effective design, manufacture, use and disposal of computer components.

Keywords: Green IT, Sustainability, Green Software, Green data centers, Green Protocols

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INTRODUCTION

Information Technology plays a big role in modern age. It is vital and integral part of business world starting from small business to multinational organizations maintaining mainframes and standard databases. However, Computer systems used in this IT industry are affecting environment badly throughout their lifecycle from manufacturing to disposal. Environmental impacts like GHG emissions, exposure to toxic chemicals, e-Waste are major issues concerning IT. Green IT is seen as a solution to all these major concerns as it encompasses various practices, policies, strategies and software tools to promote environment sustainability. Green IT provides an opportunity to use our IT systems in environment friendly way. It guides us to use computer systems in energy efficient way by reducing power consumption, GHG emissions, developing sustainable software tools and effective use of IT resources.

With increasing public awareness of environmental issues, customers now take into consideration the company's environmental record and green initiatives. Thus Green IT is drawing attention of IT industries, manufacturers, suppliers and service providers. Many regulatory laws and non regulatory government initiatives are supporting the wave of Green IT.

The main objective of this paper is to introduce the holistic and environmental perspective of Green IT. Section II describes environmental impacts and environmental sustainability for IT. The strategies for greening IT are analyzed in Section III. Regulating Green IT with the help of laws, standards and protocols are discussed in section IV.

- Environmental impacts of it

Computer systems are affecting environment throughout their lifecycle from manufacturing to disposal [2]. Environmental impacts of IT are as follows.

- *GHG Emissions*

Computer systems consume huge amount of electricity. This electricity is generated by burning fossil fuel like coal, gas and oil. They emit greenhouse gas (GHG) that is hazardous to environment. GHG consist of carbon dioxide (CO2), methane, nitrous oxide, CFC gases polluting environment. These chemicals lead to global warming that changes global climate and weather pattern. GHG emissions can be controlled by reducing power consumption by computer systems. Energy conservation methods like turning monitor off, keeping machine in standby mode when not in use reduces power consumption which ultimately reduces GHG emissions.

- *Exposure to toxic chemicals*

Manufacturing of IT hardware involves use of toxic chemicals and compounds posing health related problems [4]. These toxic chemicals and compounds are as follows.

i. Lead: It is found in CRT monitor and solder of circuit board. It affects nervous system, kidneys and reproductive system.

ii. Cadmium: It is found in monitor glass, cables and batteries. It damages kidney and bones.

iii. Mercury: It is found in circuit boards and switches. It causes itching and burning of skin.

iv. Hexavalent chromium, polybrominated biphenyls, polyvinyl chloride, polybrominated diphenyls: It causes lung disease and damage to thyroid and reproductive system.

- *e-Waste*

e-Waste or electronic waste is any unwanted or damaged electronic/electrical component. It is also called as technotrash. Computer manufacturing process produces lot of waste that cannot be disposed easily. e-Waste is thrown out with regular trash resulting in landfills polluting earth and water. It contains non biodegradable material which leaks into the ground causing hazardous effects to plants and water. e-Waste is usually sent to developing countries where people burn e-waste which results in hazardous smoke in air polluting water and air. These people are thus exposed to e-waste chemicals and compound and they fall prey to diseases like skin cancer, lung cancer, brain damage and kidney diseases. e-Waste can be minimized by three Rs of Green IT viz. Reuse, Refurbish and Recycle. Reuse is upgrading old computers and using it all over again. Refurbishing is replacing some old parts and upgrading computer according to requirement. Use of potential disposal and recycling methods can cut down amount of e-waste.

- *Energy Consumption*

All Information and Communication Technology (ICT) devices consume huge amount of energy. This energy is generated by using natural resources like trees, fossil fuel, water and coal. The energy consumption by ICT devices should be reduced to conserve natural resources.

- Greening it

The aim of Greening IT is to reduce GHG emissions, energy consumption, e-waste and promote reusability of computing devices to achieve sustainability. IT lies at epicenter of prospects of

energy savings and cost cutting. It covers domains and devices like desktops, mobile computing stations, networks, communication systems and data centers which consume huge amount of electricity[3]. The challenge of such massive power consumption also offers an opportunity to reexamine IT systems to analyze energy consumption and resource utilization. In view of this IT industry should support "go green" movement to achieve environment sustainability. The remarkable initiatives for greening IT are discussed here.

- *Green Data Centers*

The growth of internet has resulted in digitization of modern world and revolution of entire IT industry. Now computers and Internet is not limited to professionals and engineers but it has become a daily activity of common man through Facebook, Twitter, Google, Amazon and YouTube. We are consuming and producing huge data content as we use social networking sites, blogs, online shopping and photo sharing portals. This has given rise to increasing needs of data centers. Data center is central repository for data storage and management. For example National climatic data center is a data center that maintains entire information for weather forecast. Data centers have many environmental challenges and concerns to face. They emit CO2 and consume huge amount of electricity[1][8]. Surveys show that digital warehouses consume approximately 30 billion watts of electricity, which is equivalent to the output of 30 nuclear plants. A single data center consumes electricity required to run a small town. To reduce running cost in data centers energy efficient technologies should be used [5]. They are as follows

i. Data center infrastructure management (DCIM)

It focuses on data center design, system management functions, capacity planning and energy management.

ii. Free air cooling

In data centers usually heavy refrigeration and air cooling system that consume huge amount of electricity are used. Free air cooling can be used instead of this as it saves energy by using natural air for cooling.

iii. Use of renewable energy

It includes use of wind energy and gas turbines to satisfy energy requirements of data centers.

iv. Low power servers

Low power servers cuts down electricity cost of data centers.

v. Modular data centers.

Modular data centers are portable readymade data center in a box. They can be scaled and deployed quickly. HP EcoPod is a modular data centre that supports more than 4,000 servers.

vi. Cloud computing

It offers high CPU utilization and hence saves energy. Cloud resources are shared and reallocated as per demand and requirement of users. This approach maximizes computing power and reduces cost of resources by using less power, rack space and air conditioning.

- *Green PC's Notebooks and servers*

Any device consumes considerable amount of energy when in use. This energy consumption has adverse effects on environment. All computer components should be used in energy efficient manner [7]. The energy requirements of different electronic devices are different. Some of them are as follows

i. Notebook Computers

The energy consumable parts in notebook computers are

Charger: The charger should be disconnected from the power socket when not in use to save power.

Monitors: A brighter screen consumes more power so brightness of monitor can be reduced to appropriate level. Switch off monitor when not in use.

Processor: A processor has many applications and processes running in background. Stop background processes and other applications when not in use. The laptop takes more time to boot if more number of processes is set at start up, so they must be kept to minimum number. Run the processor at lower frequency to save power.

Hard Disk: Being a physical device, hard disk consumes lot of power. Hence it should be used only when required. Hard disk spinning consumes lot of energy, so defragment hard disk which lessens the spinning of hard disk. Use solid state drives (SSDs) as they consume less energy than hard disk drives(HDDs). Apply power saving options that switch off hard disk when not in use.

Peripheral devices: Unplug peripheral devices as they consume power even when not in use.

Power Modes: Notebook computers operate in two power modes.

a. Stand-by: This mode retains the state of system whereas internal devices and optical drives are powered off.

b. Hibernate Mode: It shuts down laptop completely but still retains its powered on state. It takes more time to resume in this mode.

Power management software allows users to set timings when computers can automatically go to stand by or hibernate mode.

ii. Desktop Computers

Desktop computers are fixed machines at a single location. We can use following strategies to reduce power consumption in desktop computers.

- CRT monitors in these machines can be replaced by LCD or LED as CRT consumes lot of power.
- Stop background processes and other applications when not in use.
- Run the processor at lower frequency.
- Hard disk should be used only when required.
- Hard disk spinning consumes lot of energy, so defragment hard disk which lessens the spinning of hard disk.
- Avoid having desktops switched on all the time. For this Remote wake up methodologies have been devised.
- Magic packet technology commonly referred as Wake On LAN(WOL) is used to achieve remote wake up methodology. In this technology, Network Interface Controller (NIC) wakes up the computer from any remote location, removing the need to have desktops switched on all the time. Tools like Night Watchman help enterprises to centrally and remotely power down desktops.

iii. Servers

Server computers provide services to other computers in the network. File Servers, Web servers and database servers are all server computers with powerful CPUs and large amount of memory. Server computers consume large amount of power as they are continuously in power on mode. Better cooling mechanisms are required to save power as they generate large amount of heat.

iv. Mobile Devices

All mobile devices like PDAs, mobile phones use rechargeable battery charged by external chargers. Chargers should be unplugged when not in use as they consume power even when they are not charging battery.

v. Specialized devices

Specialized devices like set top boxes, play stations, X-ray machines, CT scanners should be unplugged when not in use as they consume lot of power in power on mode.

- *Green Data Storage*

There are different types of data storage media based on their configuration, complexity, size, type of data, data access patterns and importance of data. Due to increasing growth of storage capacity and necessary redundancy of data centers' and other large scale IT facilities, storage systems are consuming more power and contributing to greater carbon footprints [10]. Hence data storage power consumption has drawn attention to the issue of reducing power consumption to make data storage systems greener.

Energy consumption in hard disk is more due to its moving components like spindle motor and head assembly etc. To optimize the energy consumption in hard disk, different methods or techniques are used a

State transitioning: State transitioning technique tries to turnoff spindle motor when not serving any request or during idle periods.

Caching: It holds the data that has been recently written on or retrieved from the disk.

Dynamic RPM: It dynamically modulates rotations of the platters or dynamically changes speed of spinning of the disks. Slowing down the spinning of platters saves lots of power.

The techniques that are used at system level are as follows.

RAID with power awareness: EERAID (Energy Efficient Redundant and Inexpensive Disk Array) and PARAID (Power-Aware Redundant Array of Inexpensive Disk Array) are used to reduce power consumption in different disks in RAID group. In EERAID the idea is to conduct I/O request scheduling and cache Management with the awareness of redundancy and power state of the disks in RAID group. Energy consumption is mostly low in low power state disk and high in high power state disk, if there is a I/O request for a low power state disk, that request can be rescheduled or transferred to high power state disk(based on redundancy) to make the disk remain in low power state. Therefore those disks which remain in low power state helps to elongate idle period and reduce energy consumption. In PARAID, number of powered on disks or high power state disks are varied depending on the load. More loads, number of power on disks will be more. Load decreases then number of power on disk also decreases by spinning down the disks.

Power aware data layout: It work on disk access pattern by optimizing data layout. It includes

- PDC (Popular Data Concentration): In this technique data is classified on the basis of file popularity, size and access characteristics. The most popular files are placed on the subset of disks which are powered on. Due to this the idle period of remaining disks increases. Longer idle periods leads to transition from active state to standby state hence more power can be saved. The most popular files can be placed on NAND flash or hard disk. It has only limitation that request to access unpopular file may lead to spinning up the disk again.

- MAID (Massive Array of Idle Disk): This technique is based on data migration. MAID copy files based on their temporal locality to other disks. A small subset of disk is used as cache where data is cached to exploit temporal locality. Remaining disks are spinned up on demand. MAID is mostly used in applications such a disk based backup and archival etc.

- Green Store**:** MAID has limitation that it cannot be applied to online storage systems. This limitation can be overcome by Green store. It uses hints generated by the application to manage MAID cache. Application hints are useful to minimize cache miss. This scheme requires 40% less energy as compared to Non-MAID solutions.

HSM: HSM store most of the enterprise data on slower devices and they migrate / copy the data to faster device on demand. HSM closely monitor the data access pattern, predicts the

future data usage pattern. The working of HSM is transparent to user, user is unaware of location of data and how to access the data.

Example : Two-tier example of HSM

Frequently accessed data are stored on faster devices like hard disk and on the other hand less frequently accessed data is placed on slower devices like tapes. Data is copied to tape if the data is not used or accessed for the given threshold time. If accessed then it will be moved back to the disk without user intervention.

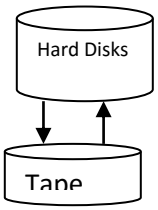

Fig. 1 : Two tier architecture

Example : Three-tier example of HSM

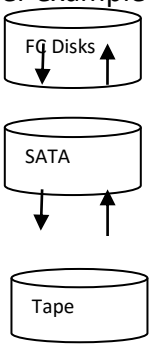

Fig. 2: Three tier architecture

The FC disk, SATA disk and tape are the 3 tier of HSM storage system. If the data is not accessed for a specified period of time then the data will be migrated from FC disk to SATA. Even after that if data is not accessed for a threshold time it will be moved to tapes which are slower and cheaper than SATA and FC. In HSM, moving least accessed data to slower devices reduces power consumption.

- Storage virtualization and cloud storage: Storage virtualization is grouping the physical storage from multiple network storage devices in such a way that it appears to be single logical unit that can be managed from single console. The major reasons to implement storage virtualization is to improve storage management in different environment, increased storage use, increased availability, better estimation of idle time. It is mostly used in data centre storage and Storage Area Network (SAN).

Green Cloud Computing*:* It is a data storage model for storing data online instead of storing the data to local storage devices. Cloud storage facility is offered usually by third parties, where the data get stored on multiple host servers. The user accesses data to or from these host servers using internet. For providing this facility the host parties or cloud storage provider gets paid depending upon the storage usage. The fee paid to the cloud storage provider by individual user or any company is much less than the cost of purchasing the storage devices and maintaining them. Cost in terms of energy is also reduced as user need not buy and maintain these storage devices and the tedious task of storage management is transferred to cloud storage provider. The service provider have all the responsibilities regarding management of power, storage space etc. The service provider itself can use different techniques for storage power management with HSM, virtualization, power -aware data layout etc. to increase storage efficiency and reduce device idle time leading to power management.

- Green Software:

Well behaved software helps energy saving software to work. Energy saving software techniques are as shown in Fig.

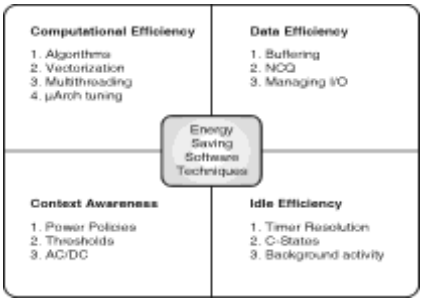

Fig 3. Energy Saving Software techniques

i. Computational Efficiency

Computational efficiency is completing the task quickly with minimal energy consumption. It is achieved by using following techniques:

a. Efficient Algorithms: Use algorithm or functions instead of script as algorithms are faster. Choice of algorithms and data structures makes a difference in application's performance. The best algorithm to solve a given problem is decided on the basis of architecture, design and data structures. A better algorithm saves time and energy.

b. Vectorization: Vectorization gives better power benefits by using single instruction multiple data (SIMD) for instruction level data parallelism.

c. Multithreading: Multithreading saves time and energy as in multithreading processor runs multiple threads or processes simultaneously.

ii. Data Efficiency

Data efficiency is achieved by

a. Pre-fetching and caching (Buffering): It stores data in temporary memory in advance to speed up processing and save energy.

b. Managing Disk I/O

Low processor utilization and less energy consumption are achieved by reading data larger chunks, using asynchronous I/O with native command queuing (NCQ), using contiguous file than fragmented file for reading.

v. Context Awareness**:** Context awareness is developing application software that adapt to changes in environment. Software can take advantages of context awareness in following ways. A notebook PC can tailor its operational modes according to power source(Ac power or battery). Application can register for event notification which notifies when power is switched from AC to DC or battery threshold is reached. Information about status of other components such as USB, Bluetooth, network cards is useful for intelligent application behavior and energy savings. LAN cards and set top boxes remain active for longer time period. To reduce energy consumption by these devices, SENS (System Event Notification Service) API can be used to check if network connection is still alive.

- *Green Networking and Communications:*

The major Objectives of Green Network Protocol is to make network energy efficient, understand network protocol and optimize it, control packets during transmission and to maintain QoS of application. Efficiency of the network can be increased by the Energy - Optimizing Protocol Design which reduces number of bits associated with the transmission and minimizing network load. Green communication protocols make network green by reducing carbon emissions and contributions from EMAN working group. Carbon emissions can be reduced by enabling cleaner manufacturing, reducing transit distance, increasing recycling and reuse. EMAN working group are those groups who convert "work in progress" internet draft into formal RFC document. This document defines MIB (Management Information Base) which is used for calculating energy, efficiency, throughput and carbon emission. If we want to calculate carbon emission, it can be calculated by energy consumption, operational efficiency and device utilization. MIB involves monitoring of all network components and attributes including their current state and time spent in each state, total energy consumed by the device, current battery charge, age etc

- Regulating Green IT

Strategizing green initiatives helps managers and users to implement green IT initiatives successfully. The European Union (EU) has led environmental laws and regulations for all electrical, electronics and IT manufacturers [10]. These laws are as follows:

i. RoHS RoHS

Restriction of Hazardous Substance Directive (RoHS) restricts the use of six hazardous substances in manufacturing of electrical and electronic equipment like Lead (Pb), Cadmium (Cd), Mercury (Hg), Polybrominated biphenyls (PBB), Polybrominated diphenyl ether (PBDE) and Hexavalent chromium (Cr6+). IT equipments currently covered under RoHS are mainframes, minicomputers, servers, routers, PCs, Laptops, notebooks, notepads, typewriters, calculators, telex and telephones.

ii. REACh

It is regulation of European Union to protect environment from hazardous chemicals that are used in industrial processes as well as in our day to day life. REACh carries four processes namely registration, evaluation, authorization and restriction of certain chemicals to protect human health. It puts the responsibility on industries of finding and providing information

about chemicals. Manufacturing industries gather information about properties of chemicals, submits it to central agency European Chemicals Agency (ECHA) Helsinki. This agency manages and coordinates information to build a public database where consumers can find information about chemicals used in products.

iii. WEEE

Waste Electrical and Electronic Equipment Directive is used to address the problem of electrical and electronic waste. WEEE in addition with RoHS became European law in 2003 to restrict the use of hazardous material and recycling of electronic waste. The responsibility for disposal, recycling and reuse of WEEE is placed on manufacturers. Many countries have formed their own policy making body to design laws, regulations and policy standards**.**

TABLE I: TA

Policy making body	Policy standard
United Kingdom	Green ICT scorecard
European Union	Eco-label
Germany	Blue angel Eco label
Denmark	Green IT action plan
Japan	Green IT promotion council
Finland	Hansel Ltd.

Many industry organizations like Electronic Industries Alliance (EIA), Consumer Electronic Association (CEA), Green IT promotion council promote green IT among industry members. Some other standard bodies are ISO, Green Electronics council, US Environmental Protection Agency (EPA), Energy Star BRE Environmental Assessment Method and US Green Building Council. Green building standards such as Global e-Sustainability Initiative (GeSI) and Climate Savers Computing Initiative are associated with sector based environmental movements. GeSI supports sustainability initiatives like climate change, e-waste management, resource efficiency, energy efficiency, reducing carbon footprints and human rights. CSCI is a nonprofit organization dedicated to reducing energy consumption, GHG emissions by computers and save money and resources. It was launched in June 2007 and many companies like Dell, HP, Google,

Intel, Lenovo, Microsoft etc. have joined the initiative. Organizations supporting CSCI are committed to manufacturing or purchasing energy efficient machines and following green practices

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