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Green Computing

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ABSTRACT: *Green Computing is a recent trend towards designing, building, and operating computer systems to be energy efficient. While programs such as Energy Star have been around since the early1990s, recent concerns regarding global climate change and the energy crisis have led to renewed interest in Green Computing. Data centers are significant consumers of energy – both to power the computers as well as to provide the necessary cooling. This paper proposes a new approach to reduce energy utilization in data centers. In particular, our approach relies on consolidating services dynamically onto a subset of the available servers and temporarily shutting down servers in order to conserve energy. We present initial work on a probabilistic service dispatch algorithm that aims at minimizing the number of running servers such that they suffice for meeting the quality of service required by service-level agreements.* making the use of computers as energy-efficient as possible, and designing algorithms and systems for efficiency-related computer technologies.
ORIGINS: *In 1992, the U.S. Environmental Protection Agency launched Energy Star, a voluntary labeling program that is designed to promote and recognize energy-efficiency in monitors, climate control equipment, and other technologies. This resulted in the widespread adoption of sleep mode among consumer electronics. Concurrently, the Swedish organization TCO Development launched the TCO Certification program to promote low magnetic and electrical emissions from CRT-based computer displays; this program was later expanded to include criteria on energy consumption, ergonomics, and the use of hazardous materials in construction.*

Keywords: *Energy-stars, dispatch algorithm*

I. INTRODUCTION

Green computing, green IT or ICT Sustainability, refers to environmentally sustainable computing or IT. In the article *Harnessing Green IT: Principles and Practices*, San Murugesan defines the field of green computing as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems such as monitors, printers, storage devices, and networking and communications systems — efficiently and effectively with minimal or no impact on the environment." The goals of green computing are similar to green chemistry; reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability or biodegradability of defunct products and factory waste. Many corporate IT departments have Green Computing initiatives to reduce the environmental impacts of their IT operations. Research continues into key areas such as

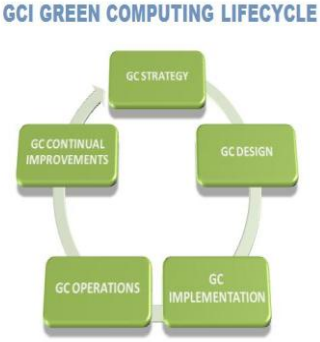
II. REGULATIONS AND INDUSTRY INITIATIVES

The Organization for Economic Co-operation and Development (OECD) has published a survey of over 90 government and industry initiatives on "Green ICTs", i.e. information and communication technologies, the environment and climate change. The report concludes that initiatives tend to concentrate on the greening ICTs themselves rather than on their actual implementation to tackle global warming and environmental degradation. In general, only 20% of initiatives have measurable targets, with government programs tending to include targets more frequently than business associations.

2.1 Government

Many governmental agencies have continued to implement standards and regulations that encourage green computing. The Energy Star program was revised in October 2006 to include stricter efficiency requirements for computer equipment, along with a tiered ranking system for approved products.

There are currently 26 US states that have established state-wide recycling programs for obsolete computers and consumer electronics equipment.



The statutes either impose an "advance recovery fee" for each unit sold at retail or require the manufacturers to reclaim the equipment at disposal.

In 2010, the American Recovery and Reinvestment Act (ARRA) was signed into legislation by President Obama. The bill allocated over $90 billion to be invested in green initiatives (renewable energy, smart grids, energy efficiency, etc.) In January 2010, the U.S. Energy Department granted $47 million of the ARRA money towards projects that aim to improve the energy efficiency of data centers. The projects will provide research on the following three areas: optimize data center hardware and software, improve power supply chain, and data center cooling technologies.

2.2 Industry

- Climate Savers Computing Initiative (CSCI) is an effort to reduce the electric power consumption of PCs in active and inactive states. The CSCI provides a catalog of green products from its member organizations, and information for reducing PC power consumption. It was started on 2007-06-12. The name stems from the World Wildlife Fund's Climate Savers program, which was launched in 1999.The WWF is also a member of the Computing Initiative.
- The Green Electronics Council offers the Electronic Product Environmental Assessment Tool (EPEAT) to assist in the purchase of "greener" computing systems. The Council evaluates computing equipment on 51 criteria - 23 required and 28 optional - that measure a product's efficiency and sustainability attributes. Products are rated Gold, Silver, or Bronze,depending on how many optional criteria they meet. On 2007-01-24, President George W. Bush issued Executive Order 13423, which requires all United States Federal agencies to use EPEAT when purchasing computer systems.
- The Green Grid is a global consortium dedicated to advancing energy efficiency in data centers and business computing ecosystems. It was founded in February 2007 by several key companies in the industry – AMD, APC, Dell, HP, IBM, Intel, Microsoft, Rackable Systems, SprayCool (purchased in 2010 by Parker), Sun Microsystems and VMware. The Green Grid has since grown to hundreds of members, including end-users and government organizations, all focused on improving data center infrastructure efficiency (DCIE).
- The Green500 list rates supercomputers by energy efficiency (megaflops/watt, encouraging a focus on efficiency rather than absolute performance.
- Green Comm Challenge is an organization that promotes the development of energy conservation technology and practices in the field of Information and Communications Technology (ICT).
- The Transaction Processing Performance Council (TPC) Energy specification augments the existing TPC benchmarks by allowing for optional publications of energy metrics alongside their performance results.
- The SPEC Power is the first industry standard benchmark that measures power consumption in relation to performance for server-class computers.

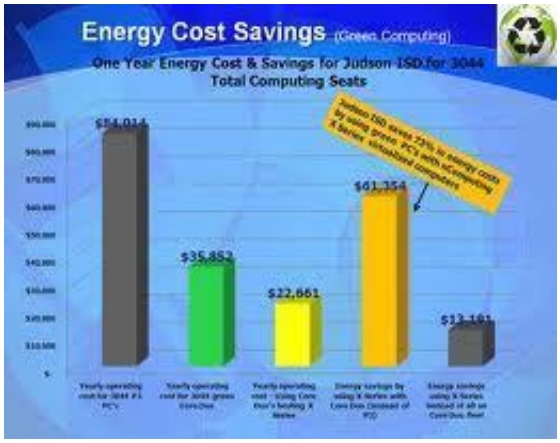


Fig.3. energy cost saving in Green Computing

III. APPROACHES

In the article Harnessing Green IT: Principles and Practices, San Murugesan defines the field of green computing as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems — such as monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal or no impact on the environment." Murugesan lays out four paths along which he believes the environmental effects of computing should be addressed: Green use, green disposal, green design, and green manufacturing. 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".

Modern IT systems rely upon a complicated mix of people, networks, and hardware; as such, a green computing initiative must cover all of these areas as well. A solution may also need to address end user satisfaction, management restructuring, regulatory compliance, and return on investment (ROI). There are also considerable fiscal motivations for companies to take control of their own power consumption; "of the power management tools available, one of the most powerful may still be simple, plain, common sense."

3.1 Product longevity

Gartner maintains that the PC manufacturing process accounts for 70% of the natural resources used in the life cycle of a PC. More recently, Fujitsu released a Life Cycle Assessment (LCA) of a desktop that show that manufacturing and end of life accounts for the majority of this laptop ecological footprint. Therefore, the biggest contribution to green computing usually is to prolong the equipment's lifetime. Another report from Gartner recommends to "Look for product longevity, including upgradability and modularity." For instance, manufacturing a new PC makes a far bigger ecological footprint than manufacturing a new RAM module to upgrade an existing one.

3.2 Data center design

Data center facilities are heavy consumers of energy, accounting for between 1.1% and 1.5% of the world's total energy use in 2010. The U.S. Department of Energy estimates that data center facilities consume up to 100 to 200 times more energy than standard office buildings.

Energy efficient data center design should address all of the energy use aspects included in a data center: from the IT equipment to the HVAC equipment to the actual location, configuration and construction of the building.

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
- Electrical systems

Additional energy efficient design opportunities specified by the U.S. Department of Energy include on-site electrical generation and recycling of waste heat.

Energy efficient data center design should help to better utilize a data center's space, and increase performance and efficiency.

IV. SOFTWARE AND DEPLOYMENT OPTIMIZATION

4.1 Algorithmic efficiency

The efficiency of algorithms has an impact on the amount of computer resources required for any given computing function and there are many efficiency trade-offs in writing programs. Algorithm changes, such as switching from a slow (e.g. linear) search algorithm to a fast (e.g. hashed or indexed) search algorithm can reduce resource usage for a given task from substantial to close-to zero. A study by a physicist at Harvard, estimated that the average Google search released 7 grams of carbon dioxide (CO_2). However, Google disputes this figure, arguing instead that a typical search produces only 0.2 grams of CO_2.

4.2 Resource allocation

Algorithms can also be used to route data to data centers where electricity is less expensive. Researchers from MIT, Carnegie Mellon University, and Akamai have tested an energy allocation algorithm that successfully routes traffic to the location with the cheapest energy costs. The researchers project up to a 40 percent savings on energy costs if their proposed algorithm were to be deployed. However, this approach does not actually reduce the amount of energy being used; it reduces only the cost to the company using it. Nonetheless, a similar strategy could be used to direct traffic to rely on energy that is produced in a more environmentally friendly or efficient way. A similar approach has also been used to cut energy usage by routing traffic away from data centers experiencing warm weather; this allows computers to be shut down to avoid using air conditioning.

Larger server centers are sometimes located where energy and land are inexpensive and readily available. Local availability of renewable energy, climate that allows outside air to be used for cooling, or locating them where the heat they produce may be used for other purposes could be factors in green siting decisions.

Approaches to actually reduce the energy consumption of network devices by proper network/device management techniques are surveyed in. The authors grouped the approaches into 4 main strategies namely,

i. Adaptive Link Rate (ALR)
ii. Interface Proxying
iii. Energy Aware Infrastructure
iv. Energy Aware Applications

4.3 Virtualizing

Computer virtualization refers to the abstraction of computer resources, such as the process of running two or more logical computer systems on one set of physical hardware. The concept originated with the IBM mainframe operating systems of the 1960s, but was commercialized for x86-compatible computers only in the 1990s. With virtualization, a system administrator could combine several physical systems into virtual machines on one single, powerful system, thereby unplugging the original hardware and reducing power and cooling consumption. Virtualization can assist in distributing work so that servers are either busy or put in a low-power sleep state. Several commercial companies and open-source projects now offer software packages to enable a transition to virtual computing. Intel Corporation and AMD have also built

proprietary virtualization enhancements to the x86 instruction set into each of their CPU product lines, in order to facilitate virtual computing.

4.4 Terminal servers

Terminal servers have also been used in green computing. When using the system, users at a terminal connect to a central server; all of the actual computing is done on the server, but the end user experiences the operating system on the terminal. These can be combined with thin clients, which use up to 1/8 the amount of energy of a normal workstation, resulting in a decrease of energy costs and consumption. There has been an increase in using terminal services with thin clients to create virtual labs. Examples of terminal server software include Terminal Services for Windows and the Linux Terminal Server Project (LTSP) for the Linux operating system.

V. POWER MANAGEMENT

The Advanced Configuration and Power Interface (ACPI), an open industry standard, allows an operating system to directly control the power-saving aspects of its underlying hardware. This allows a system to automatically turn off components such as monitors and hard drives after set periods of inactivity. In addition, a system may hibernate, where most components (including the CPU and the system RAM) are turned off. ACPI is a successor to an earlier Intel-Microsoft standard called Advanced Power Management, which allows a computer's BIOS to control power management functions.

Some programs allow the user to manually adjust the voltages supplied to the CPU, which reducesboth the amount of heat produced and electricity consumed. This process is called undervolting. Some CPUs can automatically undervolt the processor, depending on the workload; this technology is called "SpeedStep" on Intel processors, "PowerNow!"/"Cool'n'Quiet" on AMD chips, LongHaul on VIA CPUs, and LongRun with Transmeta processors.

5.1 Data center power

Data centers, which have been criticized for their extraordinarily high energy demand, are a primary focus for proponents of green computing. Data centers can potentially improve their energy and space efficiency through techniques such as storage consolidation and virtualization. Many organizations are starting to eliminate underutilized servers, which results in lower energy usage. The U.S. federal government has set a minimum 10% reduction target for data center energy usage by 2011. With the aid of a self-styled ultra-efficient evaporative cooling technology, Google Inc. has been able to reduce its energy consumption to 50% of that of the industry average.

5.2 Operating system support

The dominant desktop operating system, Microsoft Windows, has included limited PC power management features since Windows 95. Theseinitially provided for stand-by (suspend-to-RAM) and a monitor low power state. Further iterations of Windows added hibernate (suspend-to-disk) and support for the ACPI standard. Windows 2000 was the first NT-based operating system to include power management. This required major changes to the underlying operating system architecture and a new hardware driver model. Windows 2000 also introduced Group Policy, a technology that allowed administrators to centrally configure most Windows features. However, power management was not one of those features. This is probably because the power management settings design relied upon a connected set of per-user and per-machine binary registry values, effectively leaving it up to each user to configure their own power management settings.

This approach, which is not compatible with Windows Group Policy, was repeated in Windows XP. The reasons for this design decision by Microsoft are not known, and it has resulted in heavy criticism. Microsoft significantly improved this in Windows Vista by redesigning the power management system to allow basic configuration by Group Policy. The support offered is limited to a single per-computer policy. The most recent release, Windows 7 retains these limitations but does include refinements for more efficient user of operating system timers, processor power management, and display panel brightness. The most significant change in Windows 7 is in the user experience. The prominence of the default High-performance power plan has been reduced with the aim of encouraging users to save power.

There is a significant market in third-party PC power management software offering features beyond those present in the Windows operating system, available. Most products offer Active Directory integration and per-user/per-machine settings with the more advanced offering multiple power plans, scheduled power plans, anti-insomnia features and enterprise power usage reporting. Notable vendors include 1E NightWatchman, Data Synergy PowerMAN (Software), Faronics Power Save and Verdiem SURVEYOR.

5.3 Power supply

Desktop computer power supplies (PSUs) are in general 70–75% efficient, dissipating the remaining energy as heat. A certification program called 80 Plus certifies PSUs that are at least 80% efficient; typically these models are drop-in replacements for older, less efficient PSUs of the same form factor. As of July 20, 2007, all new Energy Star 4.0-certified desktop PSUs must be at least 80% efficient.

5.4 Storage

Smaller form factor (e.g., 2.5 inch) hard disk drives often consume less power per gigabyte than physically larger drives. Unlike hard disk drives,solid-state drives store data in flash memory or DRAM. With no moving parts, power consumption may be reduced somewhat for low-capacity flash-based devices.

In a recent case study, Fusion-io, manufacturer of solid state storage devices, managed to reduce the energy use and

operating costs of MySpace data centers by 80% while increasing performance speeds beyond that which had been attainable via multiple hard disk drives in Raid 0. In response, MySpace was able to retire several of their servers.

As hard drive prices have fallen, storage farms have tended to increase in capacity to make more data available online. This includes archival and backup data that would formerly have been saved on tape or other offline storage. The increase in online storage has increased power consumption. Reducing the power consumed by large storage arrays, while still providing the benefits of online storage, is a subject of ongoing research.

6.5 Video card

A fast GPU may be the largest power consumer in a computer. Energy-efficient display options include:
No video card - use a shared terminal, shared thin client, or desktop sharing software if display required.
Use motherboard video output - typically low 3D performance and low power.
Select a GPU based on low idle power, average wattage, or performance per watt.

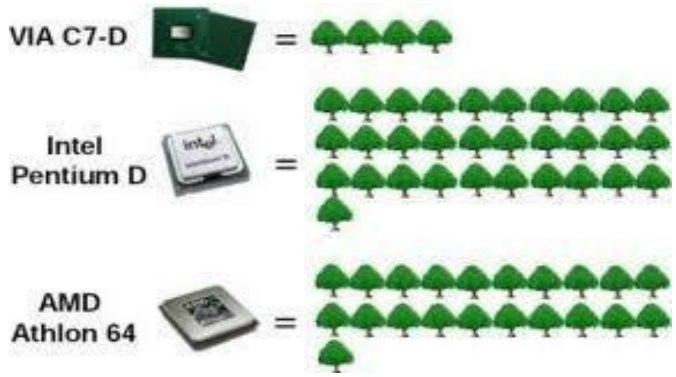


Fig.4.Energy efficient display options

5.6 Display

CRT monitors typically use more power than LCD monitors. They also contain significant amounts of lead. LCD monitors typically use a cold-cathode fluorescent bulb to provide light for the display. Some newer displays use an array of light-emitting diodes (LEDs) in place of the fluorescent bulb, which reduces the amount of electricity used by the display. Fluorescent back-lights also contain mercury, whereas LED back-lights do not.

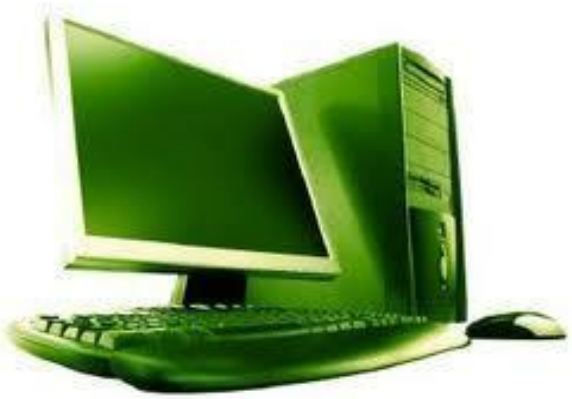


Fig.5.Display in Green Computing

VI. MATERIALS RECYCLING

Recycling computing equipment can keep harmful materials such as lead, mercury, and hexavalent chromium out of landfills, and can also replace equipment that otherwise would need to be manufactured, saving further energy and emissions. Computer systems that have outlived their particular function can be re-purposed, or donated to various charities and non-profit organizations. However, many charities have recently imposed minimum system requirements for donated equipment. Additionally, parts from outdated systems may be salvaged and recycledthrough certain retail outlets and municipal or private recycling centers. Computing supplies, such as printer cartridges, paper, and batteries may be recycled as well.

Drawbacks to many of these schemes is that computers gathered through recycling drives are often shipped to developing countries where environmental standards are less strict than in North America and Europe. The Silicon Valley Toxics Coalition estimates that 80% of the post-consumer e-waste collected for recycling is shipped abroad to countries such as China and Pakistan.

In 2011, the collection rate of e-waste is still very low, even in the most ecology-responsible countries like France. In this country, e-waste collection is still at a 14% annual rate between electronic equipment sold and e-waste collected for

2006 to 2009.

The recycling of old computers raises an important privacy issue. The old storage devices still hold private information, such as emails, passwords, and credit card numbers, which can be recovered simply by someone's using software available freely on the Internet. Deletion of a file does not actually remove the file from the hard drive. Before recycling a computer, users should remove the hard drive or hard drives if there is more than one, and physically destroy it or store it somewhere safe. There are some authorized hardware recycling companies to whom the computer maybe given for recycling, and they typically sign a non-disclosure agreement.

Fig.6.Material recycling in Green Computing

VII. TELECOMMUTING

Teleconferencing and telepresence technologies are often implemented in green computing initiatives. The advantages are many; increased worker satisfaction, reduction of greenhouse gas emissions related to travel, and increased profit margins as a result of lower overhead costs for office space, heat, lighting, etc. The savings are significant; the average annual energy consumption for U.S. office buildings is over 23 kilowatt hours per square foot, with heat, air conditioning and lighting accounting for 70% of all energy consumed. Other related initiatives, such as hotelling, reduce the square footage per employee as workers reserve space only when they need it. Many types of jobs, such as sales, consulting, and field service, integrate well with this technique.

Voice over IP (VoIP) reduces the telephony wiring infrastructure by sharing the existing Ethernet copper. VoIP and phone extension mobility also made hot desking more practical.

VIII. EDUCATION AND CERTIFICATION

8.1 Green computing programs

Degree and postgraduate programs that provide training in a range of information technology concentrations along with sustainable strategies in an effort to educate students how to build and maintain systems while reducing its negative impact on the environment. The Australian National University (ANU) offers "ICT Sustainability" as part of its information technology and engineering masters programs. Athabasca University offer a similar course "Green ICT Strategies", adapted from the ANU course notes by Tom Worthington. In the UK, Leeds Metropolitan University offers an MSc Green Computing program in both full and part-time access modes.

8.2 Green computing certifications

Some certifications demonstrate that an individual has specific green computing knowledge, including:

- Green Computing Initiative - GCI offers the Certified Green Computing User Specialist (CGCUS), Certified Green Computing Architect (CGCA) and Certified Green Computing Professional (CGCP) certifications.
- CompTIA Strata Green IT is designed for IT managers to show that they have goodknowledge of green IT practices and methods and why it is important to incorporate them into an organization.
- Information Systems Examination Board (ISEB) Foundation Certificate in Green IT is appropriate for showing an overall understanding and awareness of green computing and where its implementation can be beneficial.
- Singapore Infocomm Technology Federation (SITF) Singapore Certified Green IT Professional is an industry endorsed professional level certification offered with SITF authorized training partners. Certification requires completion of a four day instructor-led core course, plus a one day elective from an authorized vendor.

Australian Computer Society (ACS) The ACS offers a certificate for "Green Technology Strategies" as part of the Computer Professional Education Program (CPEP). Award of a certificate requires completion of a 12 week e-learning course designed by Tom Worthington, with written assignments

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