GREEN COMPUTING EVOLVING CONCEPT TO DESIGN, DEVELOPMENT, IMPLEMENTATION USING INFORMATION TECHNOLOGY

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Abstract :

Green Figuring is an advancing idea that envelops the plan, advancement, execution, and utilization of data innovation (IT) frameworks and administrations in a naturally dependable and practical way. It includes the utilization of advancements, practices, and arrangements that limit the adverse consequence of IT on the climate while boosting its proficiency and adequacy. The reflection of Green Processing can be summed up as follows: [1]

Energy Productivity: Green Figuring accentuates the productive utilization of energy in IT frameworks and administrations. This incorporates advancing the power utilization of equipment parts, for example, servers, server farms, and end-client gadgets, through innovations, for example, power the board, dynamic voltage and recurrence scaling, and virtualization. Additionally, it involves the utilization of algorithms, software, and applications that are energy efficient and reduce energy consumption during storage, communication, and processing.

Carbon Footprint Reduction: Green Computing focuses on reducing the carbon footprint of IT systems and services, which refers to the amount of greenhouse gas emissions, such as carbon dioxide (CO_2), generated during their lifecycle. This includes using renewable energy sources, such as solar or wind power, for powering IT infrastructure, as well as optimizing the software and network configurations to minimize the energy consumption and emissions. It also involves promoting telecommuting, virtual meetings, and cloud computing, which can reduce the need for physical travel and infrastructure.

Environmental Monitoring: Green Computing involves monitoring and measuring the environmental impact of IT systems and services throughout their lifecycle. This includes assessing the energy consumption, resource usage, and emissions associated with IT operations, as well as conducting environmental audits and certifications to ensure compliance with environmental standards and regulations. It also involves using environmental monitoring tools, sensors, and analytics to identify and address areas of improvement in terms of environmental sustainability.[2]

Education and Awareness: Green Computing emphasizes the importance of education and awareness among IT professionals, users, and stakeholders about the environmental impact of

IT and the need for sustainable practices. This includes providing training and resources on green IT technologies, best practices, and policies, as well as promoting a culture of environmental responsibility and sustainability within the IT industry and beyond. It also involves engaging in public awareness campaigns, advocacy, and policy-making to promote green computing principles and practices at a societal level.

In summary, the abstraction of Green Computing involves the integration of energy efficiency, resource conservation, carbon footprint reduction, environmental monitoring, and education and awareness into the design, development, implementation, and use of IT systems and services, with the goal of minimizing the negative impact on the environment while maximizing efficiency and sustainability. Many corporate IT departments have green computing strategies to lessen the impact of their IT operations on the environment.

Resource Conservation: Green Computing promotes the responsible use of natural resources, such as water, minerals, and raw materials, in the design,

production, and disposal of IT equipment. This includes using recycled or recyclable materials, reducing the use of hazardous substances, and adopting environmentally-friendly manufacturing processes. It also involves extending the lifespan of IT equipment through refurbishment, repair, and recycling, and reducing electronic waste (e-waste) by proper disposal and recycling practices.

Introduction :

Green computing is a concept that refers to the use of environmentally sustainable and energy-efficient practices in the design, manufacture, use, and disposal of computing devices and systems. With the increasing concern for environmental sustainability, there is a growing need for reducing the carbon footprint of the IT industry. Green computing aims to achieve this goal by promoting the efficient use of resources, minimizing electronic waste, and reducing energy consumption. The field of green computing has gained importance in recent years, with many organizations adopting eco-friendly practices to reduce their environmental impact. This has led to the development of new technologies and innovations that focus on sustainability, which are now being implemented in various aspects of computing. In this context, it is essential to understand the principles of green computing and its potential benefits to the environment and society as a whole.[3]

In addition to reducing the environmental impact of computing, green computing can also have economic benefits. By adopting energy-efficient practices and technologies, organizations can reduce their energy bills, which can translate into cost savings in the long run. Furthermore, the implementation of eco-friendly practices can help organizations comply with environmental regulations and improve their brand image by showcasing their commitment to sustainability.

Green computing involves several strategies, such as virtualization, cloud computing, and data centre optimization that can help reduce energy consumption and electronic waste. Additionally, the use of renewable energy sources such as solar, wind, and hydro power can

significantly reduce the carbon footprint of computing.

The field of green computing is continuously evolving, with new technologies and innovations emerging to address the environmental challenges posed by computing. As such, it presents exciting opportunities for researchers, engineers, and organizations to develop and implement sustainable solutions for a more environmentally conscious future.[4]

Overall, green computing is a crucial aspect of modern computing, and its adoption can lead to significant benefits for the environment, society, and the economy.

Recognition of this fact has led to development of green generators, green automobiles, green energy, green chemistry as well as green computing.

Green computing is basically concerned with the computers when they are manufactured, used and disposed with no side effect on environment. Use of computer plays a vital role in our environment pollution. In this era 70 percent of energy is consumed by our computers which are not in properly used. So now there is a big need to save our environment and live a healthy life.

History Of Green Computing :

The history of Green Computing can be traced back to the early days of information technology (IT) and the growing awareness of the environmental impact of computing systems. Here is a brief timeline of the history of Green Computing:

The 1960s-1970s: The early development of computing technology saw the emergence of mainframe computers, which consumed substantial amounts of energy and required extensive cooling systems. However, environmental concerns related to computing were not yet widely recognized.[5]

The 1980s-1990s: With the rise of personal computers (PCs) and the proliferation of IT in businesses and households, concerns about the environmental impact of computing began to emerge. The focus on energy efficiency, with efforts to develop more energy-efficient hardware components and promote power- saving features in PCs and servers.

The 2000s: The concept of Green Computing gained more attention in the early 2000s,

with the growing recognition of the environmental impact of IT, including energy consumption, electronic waste, and carbon emissions. Organizations such as the Green Grid, a non-profit consortium of IT professionals, were established to promote energy-efficient data centers and best practices for IT sustainability.

2007: The U.S. Environmental Protection Agency (EPA) introduced the Energy Star for Servers program, which provided energy efficiency guidelines and certifications for server hardware, encouraging the adoption of more energy- efficient server technologies.

2008: The European Union (EU) enacted the Restriction of Hazardous Substances (RoHS) Directive, which restricted the use of hazardous substances in the manufacturing of electronic and electrical equipment, including IT equipment. This directive aimed to reduce the environmental impact of IT through the use of safer materials and recycling practices.[6]

The 2010s: The focus of Green Computing expanded beyond energy efficiency to encompass resource conservation, e-waste management, and carbon footprint reduction. Efforts were made to promote responsible manufacturing practices, such as using recycled materials, reducing electronic waste through proper disposal and recycling, and adopting circular economy principles in IT equipment production.

2015: The United Nations' Sustainable Development Goals (SDGs) were adopted, which included specific targets related to responsible consumption and production, climate action, and sustainable infrastructure. Green Computing was recognized as a key enabler for achieving these goals, and initiatives were launched to promote sustainable IT practices in alignment with the SDGs.

The 2020s: Green Computing has continued to evolve, with increasing awareness and adoption of sustainable practices in the IT industry and beyond. Solar and wind power, for powering data centers, as well as the adoption of cloud computing and virtualization technologies, to optimize resource usage and reduce carbon emissions. Efforts are also being made to raise awareness and educate IT professionals, users, and stakeholders about the importance of Green Computing and its role in mitigating the environmental impact of IT. [7]

WHY GREEN COMPUTING

Green computing is essential for several reasons. First and foremost, the IT industry has a significant impact on the environment, contributing to carbon emissions, electronic waste, and other environmental challenges.

Secondly, green computing can also lead to economic benefits. The use of energy-efficient practices and technologies can reduce energy bills, lower the cost of operation, and lead to significant savings in the long run. Additionally, eco-friendly practices can help organizations comply with environmental regulations and improve their brand image, leading to increased customer loyalty and revenue.[8]

Thirdly, green computing is crucial for sustainability. As the world becomes more dependent on computing technology, it is essential to ensure that its growth and development do not compromise the planet's sustainability. By adopting environmentally sustainable practices, the IT industry can reduce its environmental footprint and contribute to building a more sustainable future.

Finally, green computing is essential for social responsibility. The IT industry has a responsibility to the planet and society to ensure that its growth and development do not come at the expense of the environment and society's well- being. By adopting green computing practices, the industry can fulfil its social responsibility and contribute to building a better world for everyone.

In summary, green computing is essential for mitigating the environmental impact of the IT industry, leading to economic benefits, ensuring sustainability, and fulfilling social responsibility.

In addition to the reasons mentioned above, green computing can also promote innovation and technological advancement. The adoption of eco-friendly practices and technologies can lead to the development of new solutions and products that are more efficient, sustainable, and cost-effective. This can create new opportunities for businesses and organizations to innovate and differentiate themselves in the marketplace, while also contributing to global efforts to mitigate climate change.

Moreover, green computing can also have a positive impact on human health. The production and disposal of electronic devices and equipment can have harmful effects on human health, such as the release of toxic chemicals and the production of electronic waste.

Life cycle of electronic equipment and minimize its environmental impact at all stages:[9]

- Design

- Production

- Use

- Disposal

Needs:

Green computing is becoming increasingly important as the world faces pressing environmental challenges such as climate change and the depletion of natural resources. Here are some of the key needs for green computing:[10]

1. Reduce carbon footprint: By reducing energy consumption, green computing can make a significant contribution to reducing carbon emissions worldwide. This is one of the biggest needs for green computing, as carbon emissions from computers and other electronic devices continue to rise.

2. Energy conservation: Green computing practices can help conserve energy, which is a precious and finite resource. By developing and using energy-efficient hardware and software, we can reduce the demand for energy and ensure that it is used more effectively.

3. Electronic waste reduction: E-waste is a major environmental problem, as electronic devices contain hazardous materials that can pollute the environment if not disposed of properly. Green computing can help reduce e-waste by promoting longer product lifecycles, appropriate recycling and disposal, and refurbishment of older hardware.

4. Resource efficiency: Efficient use of resources, both in the manufacturing and use of electronic devices, is an essential need for green computing. This can be achieved through practices such as reducing material usage, recycling end-of-life products, and designing products to be repaired and upgraded.

5. Sustainable business practices: Green computing can also help businesses adopt more eco-friendly practices, which can improve their reputation, reduce costs, and increase profits in the long run.

Overall, the need for green computing is essential to help reduce the negative impact of technology on the environment and ensure a more sustainable future for all. By implementing green computing practices, we can reduce waste, save energy, and make a positive impact on the planet.

1. Eco-sustainable design of electronic devices :

Eco-sustainable design of electronic devices involves creating products with a focus on reducing their environmental impact throughout their lifecycle. Here are some key principles of eco-sustainable design:[11]

1. **Energy efficiency**: Devices should be designed to run as efficiently as possible, reducing energy consumption during use. This includes using energy-efficient components, optimizing software coding, and implementing power-saving features.

2. **Materials selection**: Electronic devices should be built from materials that have minimal environmental impact. Materials should be non-toxic, recyclable, and sourced from sustainable sources.

3. **Product longevity**: Devices should be designed to last as long as possible, reducing

the need for frequent upgrades and replacements. This includes designing products that are repairable and upgradable, and that are durable and resistant to wear and tear.

4.   **Waste reduction**: Devices should be designed with end-of-life in mind, with an emphasis on reducing waste and maximizing recyclability. This includes designing products that can be easily disassembled, using recycled materials in production, and ensuring that hazardous materials are safely disposed of.

5.   **Lifecycle analysis:** A lifecycle analysis should be conducted to assess the environmental impact of the product throughout its lifespan. This includes considering the environmental impact of raw materials, manufacturing, transportation, use, and disposal.

By incorporating these principles into the design process, electronic devices can be created with a focus on sustainability, reducing their environmental impact and contributing to a more sustainable future.

2.   Environmentally friendly use of computer equipment :

Here are some ways to use computer equipment in an environmentally friendly manner: [12]

1.   Power down: Turn off your computer when not in use, as leaving it on overnight or when you're away wastes energy unnecessarily.

2.   Adjust power settings: Ensure your computer is set to power-saving mode, which will help reduce energy consumption when it is idle.

3.   Use the "Sleep" mode: If you need to step away from your computer for short periods, use the "Sleep" mode instead of powering it down. This mode uses considerably less energy than the normal operating mode.

4.   Recycle your electronic waste: Many computer components are toxic and

5.   can harm the environment if they are not disposed of properly. Instead of throwing them away, recycle them at designated e-waste recycling canters.

By practicing environmentally friendly use of computer equipment, you can help reduce your impact on the environment and conserve our natural resources for future generations.

3.Cloude Computing :

Cloud computing is a model of computing that allows users to access and use computing resources over the internet, such as servers, storage, software applications, and databases. Instead of owning and maintaining physical infrastructure, cloud computing users rent access to these services from a cloud services provider.[13]

Green cloud computing is a subset of cloud computing that focuses on reducing the environmental impact of cloud computing services. It involves implementing eco-friendly practices and technologies to reduce the energy consumption and carbon footprint of cloud services while improving efficiency and lowering costs. Here are some principles of green cloud computing:

a.   Energy efficiency: Cloud providers can improve energy efficiency by using energy-efficient data centers, employing virtualization technologies, and optimizing server utilization.

b.   Renewable energy: Use of renewable energy sources such as solar, wind, or hydro can help reduce carbon emissions and minimize the environmental impact of cloud computing.

c.   Resource optimization: Providers can maximize the use of resources such as storage, servers, and network bandwidth, and minimize waste by implementing auto-scaling technologies and efficient resource allocation.

d.   Carbon footprint reduction: Cloud providers can measure and reduce their carbon footprint by adopting carbon offsetting practices, implementing energy-efficient architectural designs, and promoting eco-friendly business practices.

Architecture Of Green Computing :

The architecture of Green Computing encompasses a holistic approach to designing, implementing, and managing computing systems with the goal of minimizing their environmental impact. It involves various components and strategies that work together to achieve sustainable and eco-friendly IT practices. Here are some key elements of the architecture of Green Computing:
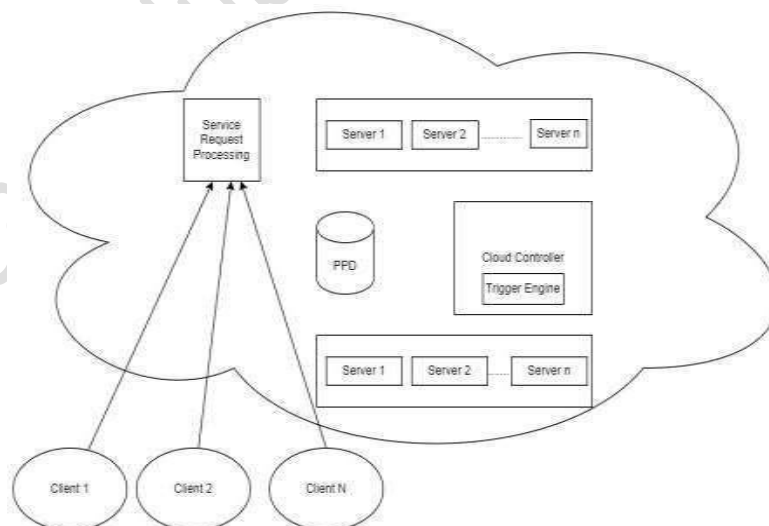
Energy-efficient hardware: Green Computing emphasizes the use of energy-efficient hardware components, including processors, memory, storage devices, and networking equipment. These components are designed to consume less power during operation, reducing the overall energy consumption of computing systems.14]

Virtualization and consolidation: Virtualization technologies allow for the efficient utilization of computing resources by consolidating multiple virtual machines on a single physical server, reducing the number of physical servers required and optimizing resource usage. This helps to minimize energy consumption, space requirements, and electronic waste from outdated hardware.

Renewable energy sources: Green Computing promotes the use of renewable energy sources, such as solar, wind, and hydroelectric power, to power computing systems. Renewable energy sources are sustainable and do not contribute to greenhouse gas emissions, making them environmentally friendly alternatives to fossil fuel-based energy sources.[26]

Data centre design and management: Data centres, which house large numbers of servers and networking equipment, play a crucial role in Green Computing. Green data centre design includes strategies such as efficient cooling systems, advanced power management, and intelligent monitoring to optimize energy usage and reduce environmental impact. **E-waste management:** Proper disposal and recycling of electronic waste (e-waste) is a critical aspect of Green Computing. This involves responsible recycling or refurbishing of obsolete or end-of-life IT equipment, as well as implementing strategies to reduce e-waste generation, such as extending the lifespan of IT equipment through upgrades and repairs.

In conclusion, the architecture of Green Computing encompasses a multi-faceted approach that integrates energy-efficient hardware, virtualization, renewable energy sources, data centre design and management, e-waste management, software optimization, user awareness, and monitoring and measurement. It aims to minimize the environmental impact of computing systems, promote sustainability, and contribute to global environmental goals.
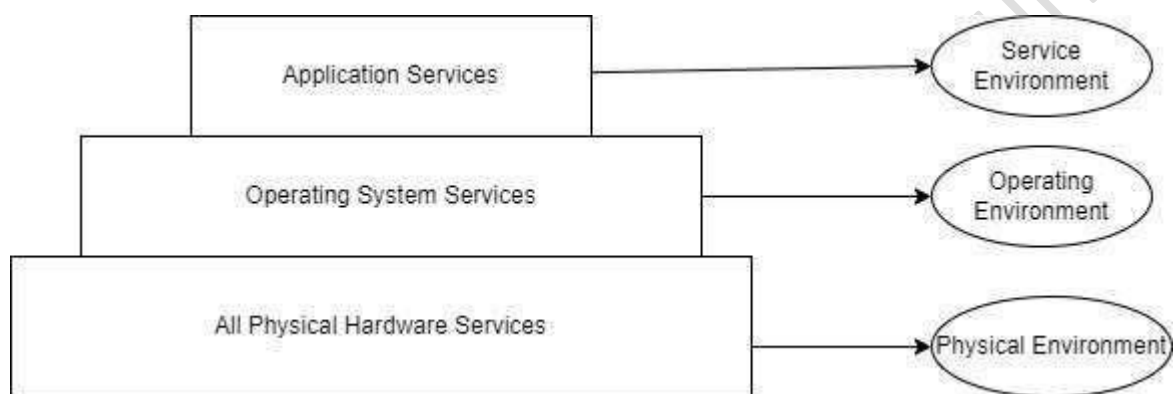

Goals of Green Computing:[15]

- **Reduce energy consumption:** As computing devices and data centers consume large amounts of energy, reducing energy consumption is a key goal of green computing. This can

be achieved by adopting energy- efficient hardware, implementing power-saving features in software, and managing data center resources efficiently.

- **Minimize carbon footprint:** green computing aims to minimize the carbon footprint of electronic devices and computing services by reducing carbon emissions from their production, use, and disposal. This can be achieved by using renewable energy sources, reducing wastage during manufacturing, and recycling end-of-life products.

- **Promote sustainability:** Green computing aims to promote environmental sustainability by encouraging the development of sustainable practices in computing. This can be achieved by promoting the use of sustainable materials in product design, reducing e-waste through responsible disposal practices, and encouraging green procurement practices.

The architecture of optimizing O.S. towards green computing has three layers namely:

STRATEGIES
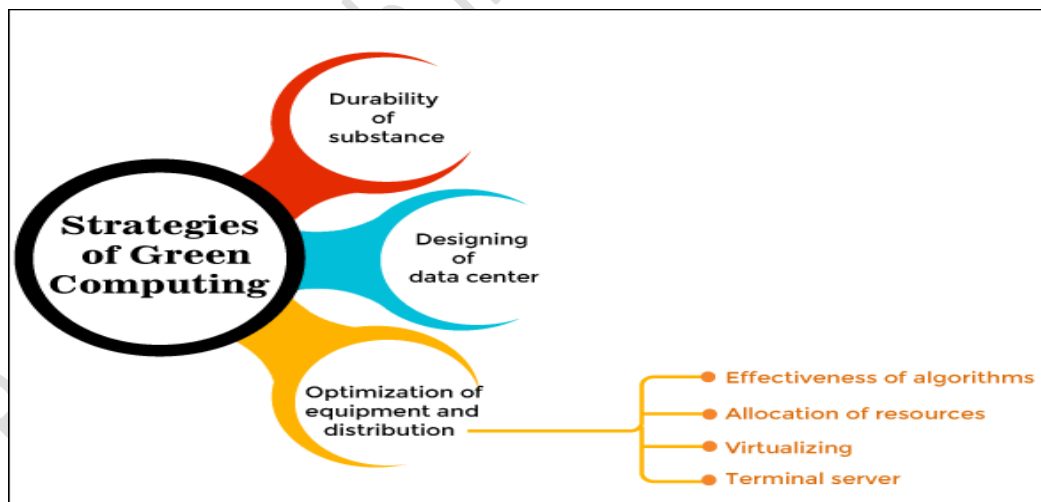
Advantages of Green Computing –[16]

- It saves power consumption and reduces the amount of heat produced from the electronic devices.
  - Reduced energy consumption: Green Computing emphasizes the use of energy-efficient hardware components, virtualization, and other strategies that minimize

energy consumption in computing systems. This results in lower electricity usage, reduced carbon emissions, and decreased environmental impact, helping to mitigate climate change and conserve valuable natural resources.

- Cost savings: Implementing Green Computing practices can lead to cost savings in the long run. By reducing energy consumption, optimizing resource usage, and extending the lifespan of IT equipment, businesses can lower their operational costs, such as electricity bills and equipment replacement costs. This can result in significant cost savings over time, improving the financial bottom line.

- Health and well-being: Green Computing practices can contribute to improved health and well-being for users and the community. For example, reducing exposure to harmful chemicals in e-waste, optimizing cooling systems in data centers to improve air quality, and promoting energy-saving behaviours among users can have positive impacts on health and well-being, creating a healthier work environment.

- Green Disposal –Reuse, Refurbish, Recycle

Disadvantages of Green Computing :

1. Upfront costs: Adopting Green Computing practices may require upfront investments in energy-efficient hardware, renewable energy sources, and other technologies or infrastructure. These initial costs can be a barrier for some businesses, especially smaller ones with limited budgets, and may require careful financial planning and resource allocation.

2. Green computing is quite costly.

3. Compatibility and interoperability issues: Implementing Green Computing practices may require changes to existing IT systems, applications, and infrastructure. Compatibility and interoperability issues may arise when integrating new technologies or making changes to existing systems, leading to potential disruptions, downtime, or additional costs for system upgrades or replacements.

4. E-waste management challenges: Proper disposal and recycling of electronic waste (e-waste) can be complex and require specialized processes to ensure environmentally responsible handling. Managing e-

5. waste can pose challenges in terms of logistics, regulations, and compliance, and may require additional resources and expertise for proper disposal or recycling, which can add to the overall costs and operational complexities.

6. Rapid technology change.

Conclusion :

Green computing is a crucial aspect of modern technology and industry that has become increasingly important in recent years. The adoption of eco-friendly practices and technologies can help reduce the environmental impact of the IT industry, promote sustainability, and drive economic benefits. By reducing energy consumption, using renewable energy sources, minimizing electronic waste, designing sustainable data centers, and adopting green

procurement practices, organizations can contribute to building a more sustainable future while also driving business success and growth. Green computing not only benefits the environment but also human health, innovation, and collaboration between different industries and stakeholders. It is an essential aspect of corporate social responsibility, and its adoption is crucial to ensuring a more sustainable and equitable world for everyone.

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