Harnessing Green Networking: A Guide to Sustainable Energy Efficiency

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In this study, we have discussed the implementation and usage of Green networking or the practice of using energy-efficient technologies. Also, we have deliberated an approach for reducing the environmental impacts of computers, networks, and related equipment. The concept of green computing refers to using computer resources efficiently, reducing energy consumption, and making sure that they don't generate unnecessary waste. This includes technologies such as low-power processors, energy-efficient LED displays, and power management systems. Additionally, there are efforts to reduce e-waste by encouraging recycling, and reusing parts and components. By implementing some strategies it is possible to limit the number of harmful emissions that result in fr0m the use of technology and reduce its carbon footprint. Since the processes to reduce environmental impacts, are becoming increasingly important in today's technology-driven world. With this in mind, this literature provides an overview of Green IoT, and Green AI with some case studies and real-life examples.

Keywords: Green Networking, Energy Efficiency, Low Power consumption, e-waste recycling, Carbon Footprint.

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1 Introduction

"We don't inherit the environment from our ancestors, we borrow it from our children". This humbling statement was given by a very famous and noted environmentalist named David Brower. If we want to keep this planet habitable in the future, we need to find ways that will help in recovering what damage has been done till now. According to Intergovernmental Panel on Climate Change (IPCC), if sustainability is defined as leaving the planet in a better condition for future generations, then we are failing miserably [1]. This is the fact that growth in technology is a major achievement for humankind, but there is a negative side to it too. As technology is moving forward on the path of success, our environment is going through rapid depletion. It's practically impossible to stop using these technologies, so we need to find a way to maintain the harmony between the growing technology and our environment [2-4]. "Green Networking" is a way to do it, if we make these technologies compatible with our nature then we can maintain sustainability without sacrificing anything [5]. Green networking is a term that refers to the use of technology as an efficient means to reduce energy consumption, costs and environmental impact. It can be used in any type of organization, from large corporate enterprises to small businesses and home environments. By implementing green networking solutions, organizations can save on energy costs while reducing their carbon footprint. Green networking involves using technologies such as virtualization, low-power devices, renewable energy sources and intelligent network design to optimize efficiency in data centers, computer networks and other IT infrastructures. For example, by utilizing virtualization technologies companies can reduce the number of physical servers needed to support applications by consolidating them into fewer machines which requires less power. Organizations can also take advantage of low-energy components like LED lighting or motion sensors to minimize electricity usage when possible.

In terms of our living and working environment, "Green" is a straightforward method of attempting to live in harmony with nature, whether in little increments or from the ground up. Going Green means taking measures to become environmentally conscious in our decision.

Today, new technologies are exhibiting a growth curve like the rise in fuel prices. Although this rush to embrace technology has resulted in the emergence of new trends and difficulties as businesses seek to fulfill their objectives, we have overlooked the influence on the earth we live in. However, in recent years, the flood has begun to shift towards increased economic, goal- oriented, and "green" substantiality. So, instead of only using technology to rescue the environment, we switched to using green technology in conjunction with evolution [6-8]. Green networking is the practice of using energy-efficient networking technology and equipment whenever possible. Green Network Technology is an example of such a technology that focuses on end-user management and energy saving in IT networks [9,10]. It is dedicated to lowering operational expenses and decreasing environmental impact throughout any company's network while offering a quick return on investment. Many companies have made social responsibility and environmental stewardship among their top priorities [11,12]. Some of the usage:

- Decrease in energy use
- Increase in energy efficiency
- From design through usage, the environmental effect of network components is considered
- The integration of infrastructure and services combines many traditional networks
- Making the network smarter
- Adherence to regulatory reporting obligations
- Promoting a cultural shift in how we think about reducing carbon emissions.

2 Data Centers and Power Consumption

Data centers are used to store, process, distribute data and applications are centralized. They are essential and important for business and utilization purposes. Around 196 to 400 terawatt-hours (TWh) is utilized by the data center sector, this equates to 1% to 2% of the annual global energy usage

in data centers. The introduction of green data centers has helped data centers to maintain their energy consumption to a great extent. In terms of green networking, data centers' wasteful use of electrical power by data center components is a major concern. In addition, coal-fired electricity generation is a major concern. Data centers store a large amount of data that is used regularly by users, businesses, the government, and academia. Today through data centers, all the world's IP traffic drives as depicted in Fig. 1.

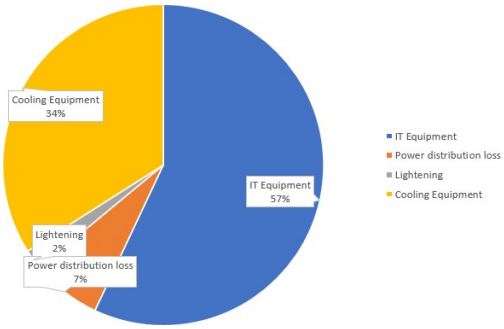

Fig. 1: Data Center Power Consumption

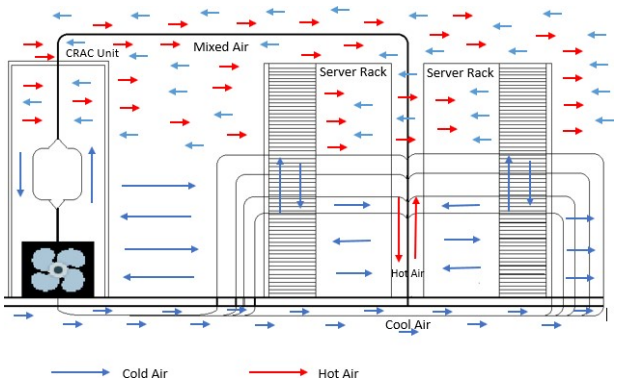

Fig. 2: Data Center Server Cooling System

Above mentioned strategy shown in Fig. 2 is one of the strategies to preserve energy that can improve the energy efficiency of data centers:

- Components: solid-state data storage devices like 80 PLUS program etc.
- Facility: data centers are squandered cooling the data center's equipment or fresh air.

3 Green Cloud Computing

One of the most well-liked developing technologies in the modern world is cloud computing. It offers computers as a utility and is a fresh and promising paradigm. It allows users to rent resources using a pay-as-you-go paradigm and offers software, data access, storage, processing, and other services via the Internet. Only the amount consumed by the clients is charged. The fundamental benefit of cloud

computing is that it allows users to access computational and data storage services on demand without having to make significant infrastructure investments. A significant quantity of power is needed to operate large data centers. So, for data centers and the cloud, energy efficiency is becoming more and more crucial. The enormous amount of carbon emissions from the IT industries is another factor endangering the environment. As a result, "Green Cloud Computing," which is more environmentally friendly, needs to be used. The term Green Cloud Computing is a combination of two words – Green, which refers to environment-friendly, and cloud computing, which is the delivery of IT service through the internet. It refers to ecologically friendly computing. It describes initiatives that aim to reduce costs and CO_2 emissions while maximizing the usage of power consumption and energy efficiency. The major goal of green computing is to research new computer systems, computing models, and applications that are inexpensive and use little power, as well as to support the development of an economy and society that is sustainable. It is a popular trend in the IT industry that refers to the environmental benefits that cloud-based services can offer to society.

3.1 Purposes of Green Cloud Computing

Green Cloud Computing has three main motives

- Promotes recycling
- Maximize energy efficiency during the complete lifecycle of the product.
- Minimize the use of hazardous IT components

By reducing energy requirements and consumption, cloud computing can help to reduce carbon emissions. It can reduce GHG emissions by combining individual data centers into large-scale facilities with efficient energy management. Cloud computing can also save energy by improving the physical environment and reducing the amount of electricity used to cool servers. Here, Fig. 3 shows the energy consumption by one Google search engine.

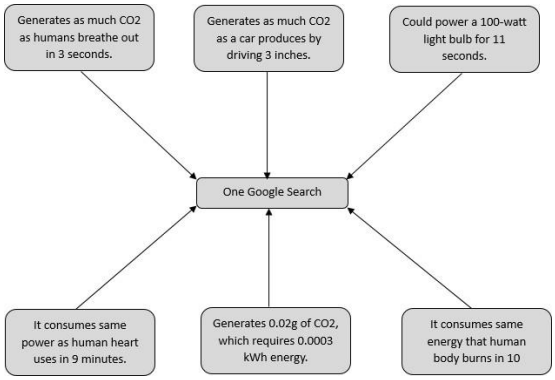

Fig.3: Energy consumed by one google search

The architectural diagram of green cloud computing is shown in Fig. 4. It is a model where both the environment and the cloud service provider benefit. By using resources effectively, green clouds boost service provider profitability in addition to being good for the environment. We can turn the current cloud environment into green-certified clouds by requiring certain management policies and traits. Energy efficiency, virtualization, multi-tenancy, consolidation, recycling, and eco-friendliness are the main attributes of green clouds. Green Cloud Computing has two perspectives:

- Green Hardware: This includes servers, network appliances, and storage hardware used in data centers as well as other information and communications technology (ICT) tools that are environmentally friendly and energy-efficient.
- Green Software Methodologies: All of the programs that oversee data centers and other cloud- based services are included in this. The aim is to rebuild and optimize the existing applications in a more energy-efficient way.

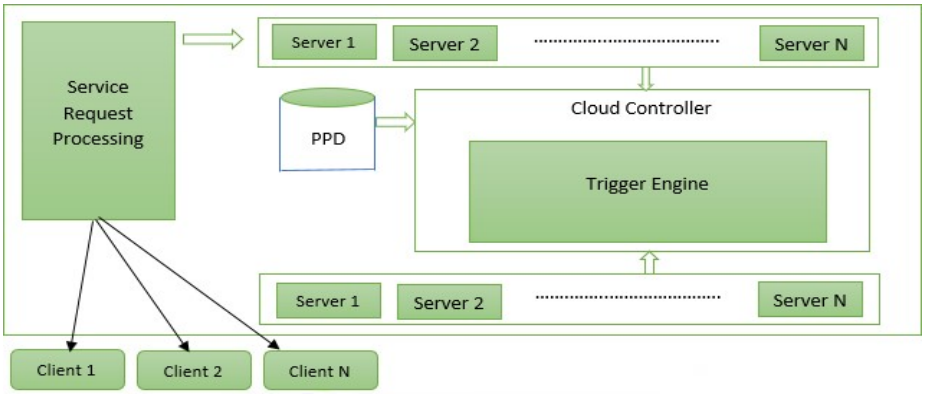

Fig. 4: Architectural diagram for green cloud computing

3.2 Green Cloud Computing Strategies

Numerous variables affect the system's functionality and energy usage. Basic energy management for servers in cloud systems is provided via a few straightforward strategies, such as turning servers on and off and putting them to sleep. Many academics have worked hard to lower the energy usage of data centers and clouds. Some research that has been done to deal with today's requirement of green computing including migration algorithm shown in Fig. 5:

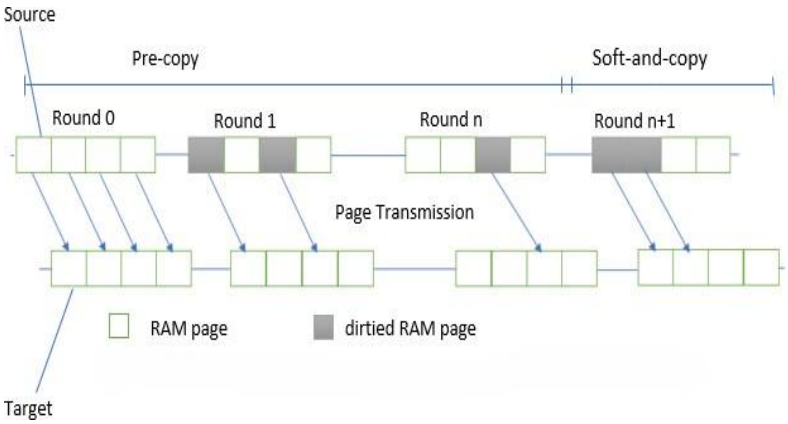

Fig. 5: Migration algorithm performs memory transfer page-wise in several rounds.

3.3 Challenges of Green Cloud Computing

Green Cloud Computing is still in its research era, and although its use has been enhanced to a great extent still many improvements are to be made. There are some challenges discussed in Fig. 6 in terms of implementing green cloud computing, some of them are as follows:

- Every computer stakeholder, from the manufacturer to the user to the business, needs to be aware of green computing.
- Every nation's government must have a uniform policy regarding green computing.
- Due to a lack of user awareness, many organizations that advocate environmental causes still do not have green computing on their agenda.
- Although green computing demonstrates how to reuse materials, many materials cannot be recycled. We need to consider these outdated tools.
- Allocating funds for resource management, cloud design, and deployment optimization remain crucial issues.
- Although this is a fundamental aspect of green clouds, at the moment privacy and security issues are affecting multi-tenancy. Future research will face significant hurdles in designing protected multi-tenant architectures and privacy-preserving secured access to multi-tenant modules.

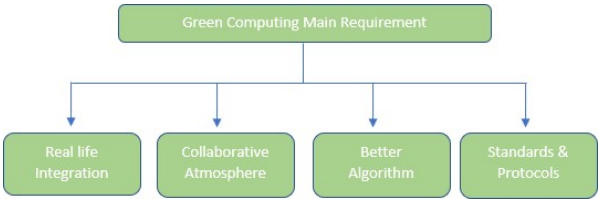

Fig. 6: Challenges of Green Computing

4 Green Cloud Computing Applications

We may not realize this yet, but collectively the computers in people's homes can provide the same service as the cloud data centers, and in homes with a renewable supply that data service could be powered by 100% green energy, plus there are no downsides. Green Cloud computing applications can only access your computer when you choose and you will be paid for the time and energy it consumes. Using these apps highly encrypted data files running in a virtualized environment on your computer are processed using spare or unused processor time entirely dictated by you, like when you are sleeping with absolutely no risk to your data. You will be in total control of how much available processor and or green energy you want to be paid for by choosing how and when your computer will participate. Once registered you will have the option to select your participation type in your Green Cloud account – Always, certain times of the day and when you are not using the machine. The development of these types of applications can help them in making cloud computing green very quickly.

4.1 Green Internet of Things (G-IoT)

G-IoT or Green Internet of Things proposes an energy-efficient process for both hardware and software. With the mainstream deployment of digital devices starting in 2020, the rate of linked device usage has increased dramatically. The output of connected devices is expected to skyrocket, reaching 100 billion by 2030, according to various technology experts, who have noted an alarming increase in energy usage that is rising every day. The Internet of Things (IoT) is anticipated to play a big part in

managing the management of majority of depleting resources like water, fuel, food, etc. as a result of the government's push for smart cities with large investments. The real-time implementation of these applications, however, necessitates a high rate of communication across massive IoT devices. Since analysts predict a phenomenal increase in data rate and large content size in the next years, this undermines the cost of how these devices will affect carbon intake and emissions into the environment. Numerous green technologies, including green RFID tags, green sensor networks, and green cloud computing networks, have grown in importance as interest in the "Green IoT" has increased. A green wireless sensor network (WSN) has emerged as a key element in enabling green IoT among these.

- **Green RFID:** Utilizing the benefits of RFID tags by making them smaller to utilize less non-biodegradable material will help significantly reduce waste since the tags are rarely recyclable. The designers can also create energy-efficient tag estimate techniques.
- **Green WSN:** Another method in the Green IoT and its Applications in real-time is to reduce the amount of data that is communicated across the communication interface by aggregating, adaptive sampling, and compression.
- **Green M2M:** Intelligently managing transmission power, activity scheduling, creating effective communication protocols, etc. are some more technologies of Green IoT and its Applications.

4.1.1 Life-Cycle of G-IoT

- **Design:** Designing and developing cooling systems, computers, servers, and energy-efficient hardware.
- **Production:** While production the energy emission must be low and energy efficiency must be high, so there is no scope for wastage.
- Utilization: minimizing the power consumption of computer systems and other information systems.
- **Decomposition:** Safe decomposition or recycling of computer or computer parts.

Various Green IoT technologies have been discussed below in Fig. 7 where various devices are interconnecting the devices in an energy-efficient manner that aims to reduce and minimize CO_2 emissions, greenhouse gas emissions, and power usage, by utilizing energy-efficient communication protocols, computing devices, and network-based designs that make the best use of available bandwidth.

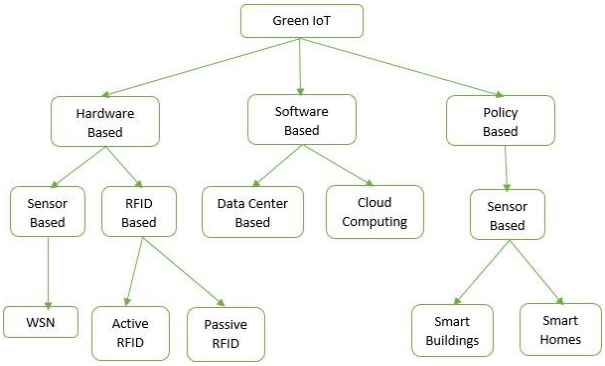

Fig. 7: Green IoT technologies

4.1.2 Potential of G-IoT in Hardware

- To save energy in an IoT network, integrated circuit (IC) design is crucial. G-IoT improves the network architecture by combining the sensors and processing power in the same chip which results in the reduction of infrastructure energy consumption, carbon footprint, traffic, and e- waste.
- Processors can be split into two cores; one core is for low computing tasks and another one is for the high processing task.
- Radio Frequency Identification (RFID) tag is a small microchip connected to a radio that sends and receives signals, it is also a promising wireless system of green IoT.

4.1.3 Potential of G-IoT in Software

Green Data Centers are used to store, manage and disseminate the data that is generated by things, systems, users, government, etc. An architecture in which a Client-Server Model is employed and an Orchestration Agent (OA) is in charge of data center administration and context evaluation of servers for resource efficiency. By reducing the number of hardware resources needed for an architecture, virtualization can reduce energy consumption. a four-layer virtualization architecture based on mixed integer linear programming (MILP), with networking components at the bottom with IoT devices at the top. As a result, energy usage is considerably lower than it was with the previous design.

The incremental impact of new technologies by assessing the resource impact of corporate and commercial technologies on power, fuel usage, eWaste, CO_2 emissions, and water usage. The analysis showed that manufacturing new IoT technologies will raise global electricity demand by 34 terawatt-hours (TWh) by 2030, but that IoT solutions will also lower electricity use by more than 1.6 petawatt-hours (PWh), enough electricity to support more than 1.6 billion people. By comparison, the worldwide ICT industry's overall electricity usage is expected to rise to roughly 8 PWh by 2030, implying that new IoT technologies will save around 20% of the industry's entire power consumption.

4.1.4 Real-Life G-IoT Example

- **Smart Grid:** To help manage energy sources and customer usage, the smart grid is a communication system that gathers data from numerous electrical system sensors. To provide power at the highest possible quality and price refers to the grid's ability to dynamically change and re-adjust dynamically. To maintain the safety and security of the power network, this aids in coordinating the quantity of energy used. The Smart grid makes use of a variety of renewable energy sources, including nuclear, solar, wind, and thermal power plants. To help manage energy sources and customer usage, the smart grid is a communication system that gathers data from numerous electrical system sensors. To provide power at the highest possible quality and price refers to the grid's ability to dynamically change and re-adjust dynamically.

- **Smart Cities:** IoT may be defined as the effective use of energy to allow a sustainable and smart world. To turn big cities into sustainable living places, equipping them with green IoT devices is a promising solution. This will bring benefits such as efficient use of energy, reduced CO_2 emissions, increased security, and useful solutions to help people.

- **Intelligent Transportation System:** With the benefit of efficiently overseeing traffic, keeping freight on schedule, and giving customers real-time access to view current location and predict arrival time to a specific location determined via RFID.

4.2 Green Artificial Intelligence

The business world is ready for artificial intelligence (AI). 35% of businesses said they were utilizing AI in day-to-day operations in 2021. Another 42% claimed to be doing their own AI research. Given these figures, it is no longer reasonable to believe that artificial intelligence is only a fad in business. The complexity of the problems to be tackled is growing along with the number of use cases. As a result, the size and quantity of AI models must increase in pace with new business concepts, and the use of these models must become increasingly commonplace. We know that AI is the future. Thus, energy efficiency in AI is very important for broader and long-standing interest in environmentally friendly research. We need to develop sustainable AI that not only satisfies the existing and growing demands but also works towards lower computational costs and carbon emissions. A movement known as "Green AI" seeks to provide a more effective and environmentally sensitive design of artificial intelligence to academics and businesses. This movement has been sparked by the ongoing introduction of AI into businesses and the resulting increase in CO2 consumption. Many companies like Google, use AI to predict the supply and demand of energy and to improve energy efficiency. This has successfully resulted in cooling down its data centers by 40%. AI can also help to improve traffic congestion in real-time. Around 70% of the electricity generated is used to power companies and buildings, with 60% of that being squandered. That's billions of dollars spent on energy production that we haven't used. To prevent this from happening, we must first comprehend where and how the waste occurs. Benefits of developing Green AI:

- Green AI could assist in the development of renewable energy sources and help us wean ourselves off of fossil fuels.
- It can assist us to use resources more efficiently for future generations.
- Green AI can help is boosting agricultural productivity by reducing the need for land, water, and other resources.

Green AI is undoubtedly a fantastic alternative for lowering computing costs, cutting carbon emissions, and changing people's perceptions of AI. Future green AI will be produced more affordably and sustainably than ever before. In the world of urban policy, discussions about smart cities and artificial intelligence (AI) are among the most common. However, most attempts to use AI to increase city efficiency have either faltered or failed to transform cities into smart cities. This is mostly because complicated urbanization issues are being addressed with narrow-minded, technologically driven, and reductionist AI approaches. In addition, the need for a green AI strategy is heightened since smart cities depend on our capacity to interact with our environments, analyze them, and come to effective, sustainable, and fair decisions.

5 Limitations of Green Networking

a. Green networking has high research and development cost.
b. It has high implementation costs thus small companies are not able to implement them.
c. Green technology is quite immature in the industry.
d. There can be many technical issues as green technology is still in the research phases.
e. There are many misconceptions and it’s possible that many eco-friendly components are not eco-friendly.

6 Conclusion

This article discusses an approach to the implementation of reducing the environmental impacts of computers, networks, and related equipment. The concept of green cloud computing, green internet of things, and green artificial intelligence refers to using our resources efficiently, reducing their energy consumption and making sure that they don't generate unnecessary waste. This includes technologies such as low-power processors, energy-efficient LED displays, and power management systems. We

have discussed green networking's goal which is to move technology in the direction of "going green". The main objective is to protect the environment while remaining efficient. Many IT industries have grown in such a way that they can continue to grow indefinitely. Networking components labeled "green" should be coupled together to see a true impact. In the latter part of study, we have discussed the green networking performance measurement system and the limitations of green IoT.

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