IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

An Energy-Efficient IoT: Green Computing for a Smarter Future

[1]Mrs.J.Saranya
Research Scholar, School of Computing Sciences, VISTAS &
Assistant Professor, Department of Computer Applications, C.T.T.E College for Women.
Chennai, India

[2] Dr.V.Divya
Assistant Professor, Department of Computer Applications (UG),
School of Computing Sciences, VISTAS,Chennai, India

Abstract

In order to create sustainable smart environments, this article offers a thorough framework for combining green computing concepts with Internet of Things (IoT) technologies. The influence of IoT devices on the environment has become a major worry as their exponential growth is expected to reach 30 billion by 2025. Our study shows that IoT system energy consumption may be lowered by 40–65% while preserving operational efficiency through the use of intelligent power management algorithms, efficient hardware architectures, and renewable energy harvesting methods. Important issues in network protocols, edge computing, cloud architecture, and hardware design are addressed by the suggested multi-layer framework. By means of comprehensive examinations of existing technologies, case studies of implementation, and comparative assessments, we provide workable plans for implementing green IoT solutions in smart cities, healthcare, and agriculture.

Future research directions in self-sustaining IoT networks and biodegradable electronics are also identified in the article. Energy management is a critical challenge for sustainable development as a result of growing energy needs brought on by the expansion of Internet of Things (IoT) networks. In order to lower energy consumption and increase the longevity of IoT networks, this study provides a thorough analysis of energy management tactics in IoT, with a particular emphasis on energy harvesting and energy-saving methods. To lower the carbon footprint and boost the effectiveness of IoT devices, the authors specifically investigate the integration of renewable energy sources, such as solar, thermal, and mechanical energy. Furthermore, the survey identifies the security flaws in energy management procedures and suggests solutions to guarantee safe and long-lasting IoT networks. The findings emphasise the importance of optimising both energy efficiency and security in future IoT deployments.

Keywords: Internet of Things (IoT), Cloud Computing, Edge Computing, Energy Consumption.

1 INTRODUCTION

As a network that connects people and physical objects, the Internet of Things (IoT) offers continuous communication and engagement across a variety of sectors, radically changing societal, corporate, and personal dynamics. People's interactions are changing as a result of this evolution, and societies and industries are moving toward a global information-based structure. Nevertheless, this growth has also resulted in a sharp rise in problems like waste, greenhouse gas emissions, and the use of natural and non-renewable resources, despite these amazing developments and advantages to many aspects of society. In fact, it is anticipated that the number of network nodes in the Internet of Things will increase significantly in the future, thus it is critical to minimize the resources needed to deploy network components and lower energy usage.Wireless Sensor Networks (WSN), one of the most significant and widely used IoT technologies, are typically composed of

small, battery-operated sensor devices that gather data and build reliable, efficient information and communication networks. However, these gadgets are typically used to perform ongoing, long-term monitoring and control tasks. Furthermore, sensors can be placed in difficult-to-reach locations, such military sites, undersea systems, dangerous areas, etc., and quickly use up their energy. Regularly changing their batteries consequently becomes a challenging and costly task. The continued functioning and usefulness of IoT devices must be ensured via energy storage and power management, as cable-powered or battery-replacement options are impracticable in severe settings.

2. Literature Review

Numerous studies and surveys on energy management for IoT networks have been published throughout the years, demonstrating the depth of this field's research. To illustrate this, the authors of ref. [1] explained battery-powered energy harvesting and conservation systems that are used in the development of WSN algorithms. For instance, the authors of ref. [2] examined energy-efficient protocols and plans for energy management and storage for these kinds of networks.
The writers of ref. [3] who studied the energy harvesting techniques used in WSN that help to enhance longevity, or the authors who focused on transmission power management and other auxiliary techniques.

Since Green IoT research is still in its infancy, energy monitoring is an important but understudied topic. Actually, in order to satisfy the Quality of Service (QoS) requirements of applications, it is crucial to measure and assess the energy consumption of IoT devices. Due to the large size and expensive cost of the existing commercial energy measurement technologies, researchers proposed a number of alternatives. The accuracy, measuring range, and complexity of these possibilities are sometimes limited, however [4]. In order to handle a variety of devices and their different levels of complexity at a reasonable cost, IoT energy monitoring methodologies must also be standardized.

As we can see, even if the IoT revolution has started to transform our lives, there are still many challenges to be resolved with regard to energy consumption and environmental issues. As a result, numerous workable methods from other fields are being researched to achieve this time-consuming objective [5].

Two main approaches are used to deal with energy management in IoT networks: energy harvesting and energy saving. Renewable energy sources including solar, wind, and mechanical power are suggested as ways to sustainably power IoT devices. To begin this paper's contribution [6], We offer a technique-based taxonomy that focuses on these two groups and summarizes the most recent developments in energy management techniques intended to prolong the life of IoT networks and lower their carbon impact. In addition to reviewing energy harvesting and conservation methods for sensor nodes, our work also examines solutions for devices with more significant resource needs. This paper's main contribution is a thorough, current analysis of the most recent energy management strategies and their contribution to the development of a more environmentally friendly Internet of Things ecosystem [7]. We provide a thorough examination of energy-harvesting and energy-saving techniques currently used in IoT networks in order to assist researchers who are interested in the newest developments in energy-efficient IoT systems [8]. Recent advancements in energy management techniques and security issues that have not yet been addressed in the body of literature on Green IoT and energy management are included in this study.

3. Background

The design and use of resources that are ecologically friendly and maintain computer capacity without deteriorating it is known as "green computing." Computer resources are recycled after use. Businesses that manufacture these gadgets ought to be more biodegradable and consume less energy. Since energy-efficient sensors make up the majority of IoT devices, industrial players have used them extensively. Additionally, these sensors assist IT in making effective use of wireless networks. Data centres offer huge data processing and storage capabilities. Platforms for cloud Computing confront the difficulty of growing number of Internet of Things devices. For real-time services, these IoT devices use edge computing since they need to be mobile and have minimal latency. In order to connect network devices at various computer tiers, fog computing is a distributed computing paradigm. It offers low-latency answers to Internet of Things devices that are not possible with centralized cloud computing infrastructures. The goal of green computing is to minimize energy use, preserve processing power, and be ecologically benign. With each generation, the technology used to manufacture computer CPUs has improved and become more energy-efficient. Meeting the requirements of green computing has become crucial, nevertheless, as the number of computing devices in use has grown. The

introduction of green computing to cloud computing aims to lower energy consumption and the use of hazardous materials in equipment.

4. INTERNET OF THINGS

In order to connect to the Internet and exchange data automatically without direct human intervention, a network of physical objects equipped with sensors, software, and communication technologies is known as the Internet of Things (IoT). Focuses on linking commonplace physical objects to computer networks, such as equipment, devices, and systems. Allows for automated processes, monitoring, and real-time data collection. Extends Internet connectivity beyond conventional PCs, playing a crucial part in contemporary computer networks. Increases convenience, accuracy, and efficiency in both industrial and daily uses. Sensors gather information and transmit it over the network to cloud or edge systems for processing and analysis.

Apps are used to present results to people, or they can be used to control actuators and systems automatically. Cloud computing is one element that contributes to the success of the Internet of Things. Through the use of Internet-based services, cloud computing allows users to complete computing activities. The Internet of Things and cloud computing are now connected, and their use together has become a kind of catalyst. These are real future technologies that will be very advantageous.

The challenge of storing, processing, and retrieving vast volumes of data has emerged as a result of the quick development of technology. The mutual usage of cloud and Internet of Things technologies is a source of great innovation. When combined, new monitoring services and advanced processing of sensory data streams will be available. Cloud computing, for instance, can be used to upload and store sensor data for later use in intelligent monitoring and activation with other devices. The objective is to turn data into insights that will motivate economical and fruitful action.

4.1 IOT CLOUD ADVANTAGES AND FUNCTIONS

There are many benefits of combining these services

• Numerous connectivity choices are offered by IoT cloud computing, suggesting extensive network access. People access cloud computing resources via a variety of devices, including computers, tablets, and mobile devices. Although this makes things easier for consumers, it also makes network access points necessary.

• Developers have on-demand access to IoT cloud computing. Stated differently, it is a web service that can be accessed without prior authorization or assistance. Access to the Internet is the sole prerequisite. The service can be scaled to meet the needs of users based on their requests. You can adjust software settings, increase storage capacity, and manage the number of users when you are quick and adaptable. This feature makes it feasible to offer deep processing power and storage.

5. CLOUD COMPUTING

Pooling resources is implied by cloud computing. It encourages more cooperation and strengthens user relationships. Security issues arise when the use of automation and IoT devices increases. Reliable encryption and authentication mechanisms are offered to businesses via cloud solutions. Last but not least, IoT cloud computing is practical since you receive exactly what you paid for. Because the provider tracks your usage statistics, prices change based on consumption. Connecting to the Internet and exchanging data between network components requires an expanding network of objects having IP addresses. Because it depends on dependability, security, economy, and performance optimization, cloud architecture needs to be well-designed. Agile development and a secure environment are produced by using well-designed CI/CD pipelines, organized services, and sandboxed environments.

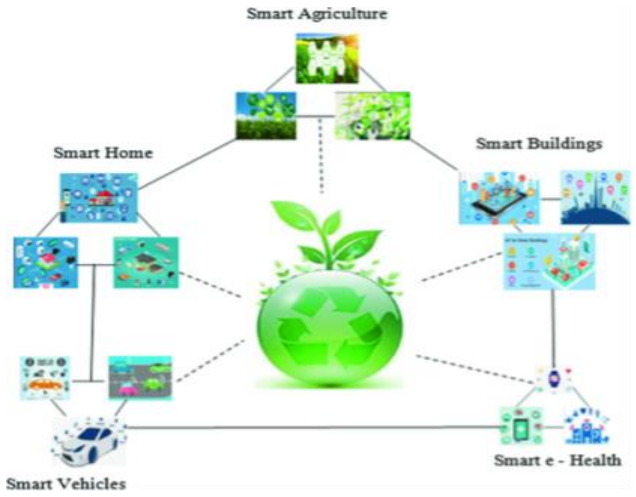

Figure 1: Green IoT (source: Application of IoT in Green Computing

5.1 Comparison of Internet of Things and Cloud Computing

Cloud computing is a centralized system that facilitates the delivery of files and data to data centres via the Internet. A centralized cloud system makes a wide range of programs and data easily accessible. The term "Internet of Things" describes gadgets that are linked to the Internet. Real-time and historical data are both stored in the Internet of Things. In addition to tracking how specific activities work, the Internet of Things can analyse and guide devices to make wise judgments. The transmission of data to data centres via the Internet is included in cloud computing. Cloud computing is classified into six categories by IBM:

- Platform as a Service (PaaS)
- Software as a Service (SaaS)
- Infrastructure as a Service (IaaS)
- Public cloud
- Private cloud
- Hybrid cloud

Connecting gadgets to the Internet is now referred to as the "Internet of Things." Cars and home appliances are examples of commonplace gadgets that may be connected to the Internet, and as the Internet of Things develops, more and more gadgets will follow suit.

5.2 Pairing with edge computing

With IoT solutions, data processing at the network edge, also known as edge computing, allows for quicker processing and reaction times. A huge factory with numerous IoT sensors installed can help illustrate how this operates. In this case, aggregating data near the border before sending it to the cloud for processing makes sense in order to minimise direct connections and avoid cloud overload. Data processing speeds up significantly in data centers that use this method. A purely edge-based approach, however, would never offer a comprehensive understanding of how a firm operates. The factory will only have individual control over each unit if there is no cloud solution. It is also incapable of comprehending how these units function in connection to one another. Because of this, organizations will only be able to take advantage of IoT advancements when the edge and cloud are combined.

The Role of Cloud Computing on the Internet of Things:

Together with the Internet of Things, cloud computing aims to increase the effectiveness of routine tasks. Since the Internet of Things produces a vast amount of data, cloud computing is about giving that data a way to get to its destination.
Amazon Web Services claims that cloud computing offers the following four advantages: • Infrastructure capacity needs don't need to be anticipated. • Saves money since you just pay for the resources you utilize; the more substantial the scale, the greater the savings.

• Platforms may be deployed globally in a matter of minutes.

• It's crucial to remember that cloud computing makes it simple to transfer big data packets created by the Internet of Things over the network. Adaptability and speed in supplying developers with resources Therefore, cloud computing plays a part in IoT by storing IoT data and making it easily accessible when needed. It is noteworthy that cloud computing provides a simple means of transporting massive data packets produced by the Internet of Things via the Internet.

5.3 VIRTUALIZATION TO PROMOTE GREEN COMPUTING

Due to the enormous amount of power that a data center uses—power that could be used to power thousands of homes—data centers and environmental lists are searching for ways to lower power consumption and make data centers more energy-efficient than they are now. Data center power consumption can be addressed by virtualization. Reducing the amount of energy used is one of the main objectives of virtually all types of virtualization. To put it simply, virtualization is the ability to make a single piece of hardware work like numerous pieces. Various user interfaces segregate distinct hardware components,

Causing each to act and function as a unique, independent entity.In the context of data centers, virtualization refers to the installation of virtual infrastructure that enables many operating systems and applications to run on fewer servers, hence lowering the total energy consumption of data centers. Data centers can decrease the size of their buildings if the number of servers is decreased. Virtualization has several benefits that directly affect productivity and benefit the environment, such as:

Moving a virtual machine from one physical server to another eliminates planned downtime. Workloads are dynamically distributed among a collection of servers, and virtualized applications have automated failover. Allocating resources is more effectively maintained and controlled. A server group's capacity to share resources is greatly enhanced by virtualization. Instead of starting at 10 to 15%, server utilization rates can be raised by up to 80%.With such enormous potential for energy savings, the energy saved per server would equal to 700 kilowatt-hour annually. The greatest way to implement green computing, Particularly in Indian data centers, is through virtualization.

5.4 APPLICATIONS OF GREEN COMPUTING IN IOT

IoT applications of green computing include sustainable data processing, energy-efficient equipment, and improved communication to lessen environmental effect.Smart homes and smart cities, where low-power IoT sensors automate trash management, traffic signals, and lighting to save electricity use, are common places for green computing. IoT devices monitor crop health, temperature, and soil moisture in smart agriculture, allowing for precision irrigation and lowering water and energy consumption. Through predictive maintenance and energy monitoring, industrial IoT uses green computing to reduce wasteful machine operation and boost productivity. Additionally, to measure the quality of the air and water while prolonging the life of the device, environmental monitoring systems include sensors that require less battery power. IoT optimizes the generation, storage, and distribution of solar and wind power, while green computing helps manage renewable energy. All things considered, these apps contribute to cheaper operating costs, longer device battery life, lower carbon emissions, and more sustainable IoT ecosystems.

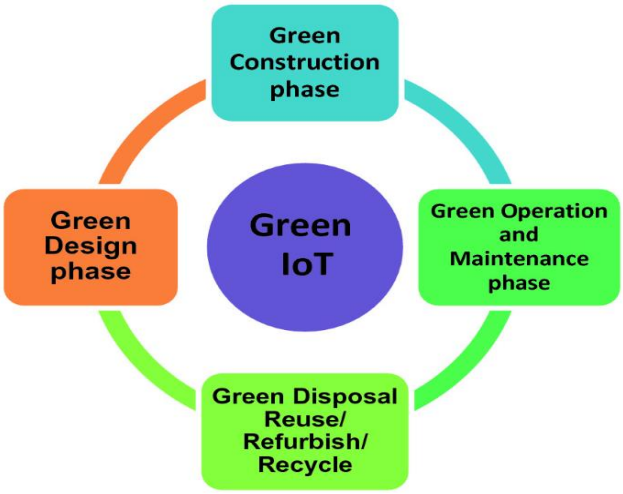

Fig.2 Applications of IoT in Green Computing

5.5 Advantages of Green Computing

Green computing optimizes technology for efficiency and environmental sustainability, which has major advantages. Significant benefits include fewer carbon footprints, lower energy usage, cheaper operating costs, and less e-waste due to longer device lifecycles. Additionally, it encourages healthier, non-toxic work conditions, facilitates regulatory compliance, and improves corporate reputation

5.6 Challenges facing Green Computing Implementation

The fast obsolescence of technology, little understanding of sustainable IT, and the high upfront costs of energy-efficient infrastructure are major obstacles to the adoption of green computing. Inadequate e-waste management, technical constraints in performance-energy trade-offs, and challenges integrating new, environmentally friendly systems with legacy infrastructure are further obstacles.

Primary Challenges in Green Computing Implementation:

- High Initial Costs: Although energy-efficient technology and infrastructure might save money over time, enterprises may be put off by the high upfront costs.
- Lack of Awareness and Expertise: Many users and businesses are either untrained in adopting sustainable practices or do not understand the advantages of green IT.
- Technological Restrictions: Greener technologies might not always be able to match the power of conventional systems, making it difficult to balance the demands of high-performance computing with energy efficiency.
- E-waste Management: Inadequate facilities for the secure recycling and disposal of outdated electronics pose serious environmental risks, especially in developing nations.
- Legacy System Compatibility: It can be challenging logistically and technically to integrate new, sustainable technology with more traditional, established IT systems.
- Rapid Obsolescence: The rapid evolution of technology necessitates regular upgrades, which runs counter to the objective of lowering e-waste and, in certain situations, increases its incorrect handling might result in data breaches, it is crucial to make sure that data is completely removed from outdated equipment before recycling or disposal.
- Data Center Power Consumption: Without specialized, expensive, or effective equipment, cooling and powering, particularly in data centers, comprise a significant energy drain that is challenging to regulate.

6. CONCLUSION

Green computing" is more than just a fad; it is essential to a sustainable future. While putting Green computing concepts into practice calls for dedication and teamwork, the long-term advantages for society, businesses, and the environment make the effort worthwhile. Green computing should be adopted now for a sustainable future. Building a healthy ecosystem requires careful study of IoT green computing. By implementing green computing methods, we can lower energy consumption throughout our computing infrastructure and produce recyclable equipment. The development of green IoT can thus be greatly aided by green computing.

7. REFERENCES

[1] Arshad, Rushan, et al. "Green IoT: An investigation on energy saving practices for 2020 and beyond." IEEE Access 5 (2017): 15667-15681.
[2] Chiang, Mung, and Tao Zhang. "Fog and IoT: An overview of research opportunities." IEEE Internet of Things Journal 3.6 (2016): 854-864.
[3] Bedi, Guneet, et al. "Review of Internet of Things (IoT) in electric power and energy systems." IEEE Internet of Things Journal 5.2 (2018): 847-870.
[4] Albreem, Mahmoud AM, et al. "Green internet of things (IoT): An overview." 2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA). IEEE, 2017.
[5] Tahiliani, Vinita, and Mavuri Dizalwar. "Green iot systems: An energy efficient perspective." 2018 Eleventh International Conference on Contemporary Computing (IC3). IEEE, 2018.
[6] Ning, Zhaolong, et al. "Green and sustainable cloud of things: Enabling collaborative edge computing." IEEE Communications Magazine 57.1 (2018): 72-78.
[7] Guo, Mian, Lei Li, and Quansheng Guan. "Energy-Efficient and Delay- Guaranteed Workload Allocation in IoT-Edge- Cloud Computing Systems." IEEE Access 7 (2019): 78685-78697
[8] Tao, Fei, et al. "CCIoT-CMfg: cloud computing and internet of thingsbased cloud manufacturing service system." IEEE Transactions on Industrial Informatics 10.2 (2014): 1435-1442.