
OVERVIEW OF GREEN IOT TECHNOLOGY AND ITS APPLICATION**Sangram Keshari Nayak^{*1}, Dr. Jitendra Sheetlani², Rasmita Rautray³ & Dr. Mukesh Tiwari⁴**^{*1,2&4}SSSUTMS, Sehore, M.P., India³Dept. of CSE, Siksha O Anusandhan Deemed to be University, Odisha, India

ABSTRACT The Internet of Things (IoT) is a broadly utilized technology today that allows billions of devices to connect and exchange massive amounts of data from one location to another at any time. In general, focusing on energy efficiency at all levels of the Internet of Things (IoT) leads to Green IoT (GloT), which lowers costs while minimizing human health risks. Green IoT depicts IoT theory with increased energy efficiency. We begin with a review of the internet of things, its architecture, and then move on to a discussion of green IoT, its applications, strategies, and the issues that arise from the overuse of energy-hungry IoT devices. The study presented in this paper focuses on energy efficiency in the Internet of Things. Some challenges, future direction, and prospects were presented by the authors.

Keywords: Internet of Things, Green IoT, Smart Cities, Energy Efficiency, Data Centre.

I. INTRODUCTION

Renewable energy blending and increased energy use are critical enablers of long-term energy transitions and climate change. The Internet of Things (IoT) is gaining popularity around the world, with its network infrastructure consisting of a variety of devices such as actuators, sensors, and other appliances that are physically embedded items capable of detecting, processing, and transferring data over the network. Modern inventions like the Internet of Things (IoT) have a wide range of applications in the energy industry, including transmission and distribution, energy supply, and demand. Any IoT-based system requires a large number of sensing devices, computing components, and communication technologies to grow and evolve. Even if sensing and processing devices are powered by batteries, any IoT-based system must extend and adapt with a large number of sensing devices, processing elements, and communication technologies. Furthermore, for the system's QoS, the communication devices must be capable of providing an uninterrupted connection. The Internet of Things' information network easily integrates physical items, allowing them to actively engage in business activities [1]. As a result, information about their current state, the environment, production, and maintenance activities with scheduling, among other things, could be supplied. However, before the IoT goal can be realized, a number of fundamental challenges must be overcome, including both technological and sociological tangles. The primary concerns are how to achieve full interoperability across networked devices and how to provide them with a high level of intelligence by allowing them to function in safe and secure ways for users [2]. Rising energy prices, increased environmental awareness, and altering customer preferences toward greener products, on the other hand, allow people to make spontaneous decisions to prioritize green manufacturing and energy-efficient production practices [3]. As a result, IoT system components must place a greater emphasis on energy efficiency. This paper will look at current research and efforts to design energy-efficient IoT systems by existing researchers. Energy efficiency is one of the most significant drivers of long-term development, according to the United Nations Sustainable Development Goals agenda [4].

Energy efficiency also saves money by lowering the cost of fuel supplies and imports, as well as the cost of energy generation and energy-related emissions. Improving energy efficiency and optimizing energy management necessitates a thorough examination of real-time data from the energy supply chain. [5].

II. ARCHITECTURE OF IOT

IoT design must be adaptive since billions and trillions of heterogeneous things must be linked. There are numerous potential IoT designs available, but none have come together to form a single reference model. Numerous projects have aided in the creation of a standard IoT architecture based on technology advancements and research. From the pool of architectures accessible, we will look at two that are commonly utilized by many researchers and in industry [6].

Three Layer Architecture

The most basic structure is shown in Figure 1, which is a three-layer layout [7-9]. It was first employed in the early stages of study in this sector. Perception, network, and application are the three layers that make up this system.

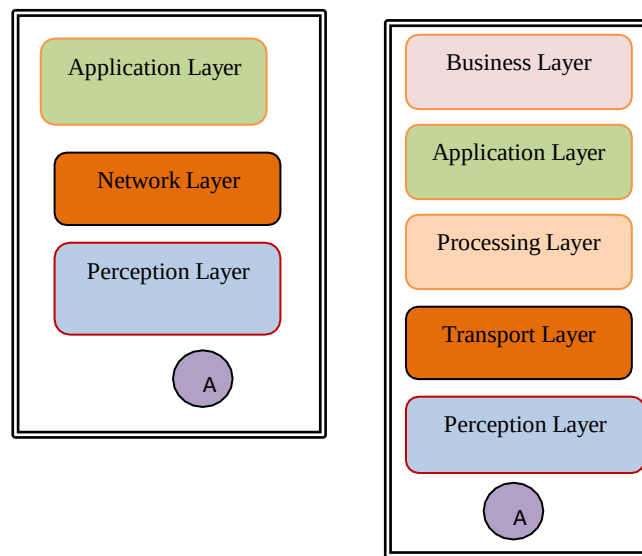


Fig. 1: Three and Five layer architecture of IOT

- i. The perception layer is the physical layer, which contains sensors for perceiving and gathering information about the environment. It recognises other intelligent devices in the area and identifies certain physical parameters.
- ii. The network layer is in charge of connecting smart devices, network devices, and servers. Its capabilities are also used for sensor data transfer and processing.
- iii. The application layer is responsible for providing application-specific services to the user. It specifies a wide range of Internet of Things applications, including smart homes, smart cities, and smart health.

The three-layer design encapsulates the Internet of Things' basic concept; yet, it is insufficient for IoT research because it often concentrates on small features. As a result, much innovative layered architecture has been published in the literature. The five-layer design [7-9], which comprises the processing and business layers, is one example. Perception, transportation, processing, application, and business are the five steps. The perception and application levels serve the same purpose as the three-layer design. The final three strata are discussed in more detail.

- i. The transport layer uses networks like Wi-Fi, 3G, LAN, Bluetooth, RFID, and NFC to convey sensor data from the perception layer to the processing layer.
- ii. The middleware layer is also known as the processing layer. Massive volumes of data from the transport layer are stored, analyzed, and processed by it. It has the ability to manage and provide a variety of services to the lower layers. Databases, cloud computing, and big data processing modules are among the technologies used.
- iii. The business layer is in charge of the IoT system as a whole, including apps, business and profit models, and user privacy. The scope of this study does not include the business layer. As a result, we're not going to talk about it any further.

Another design by Ning and Wang [9] is based on the human brain's tiers of processing. The driving factors behind it are human cognition and the ability to think, feel, remember, make decisions, and react to their surroundings. It's broken down into three sections. The first is the human brain, which is comparable to a data center's processing and data management unit. The second component of the body is the spinal cord, which resembles a distributed network of data processing nodes and smart gateways. The nerve network, which is made up of networking components and sensors, is the third component.

III. OVERVIEW OF GREEN IOT

The Internet of Things (IoT) is a global, invisible, immersive, ambient communication network and computer environment that uses cameras, smart sensors, databases, software, and data centres in a global information fabric system [10]. The Internet of Things was employed in [11] to build a green, energy-efficient campus environment.

Despite the data shown in [11], IoT elements were investigated in [12], which highlighted the benefits of IoT design in terms of how to construct a green campus by wisely and efficiently leveraging sophisticated technology. The authors of [13] proposed specific technical steps for building a future green internet.



Fig.2: Green IoT

Green IoT focuses on reducing IoT energy usage, which is critical for smart world sustainability and CO₂ emissions reduction. Green IoT entails both planning and execution. Designing computational hardware, communication protocols, energy efficiency, and networking topologies [14] are all examples of green IoT design elements, as shown in Fig. 1. The purpose of incorporating the IoT component is to minimize CO₂ emissions, pollution, and enhance energy efficiency. Despite past data, Uddin et al. [15] proposed ways for improving energy efficiency and reducing CO₂ for allowing green information technology.

Because it is equipped with sensors and connectivity add-ons, M2M can communicate with one another and comprehend the world. Sensors, on the other hand, will consume a significant amount of electricity in order to perform their functions. Green IoT tries to figure out where the relay is located and how many nodes are needed to meet energy and financial constraints in networking. In order to achieve a smart and sustainable future, green IoT plays a critical role in deploying IoT to reduce energy consumption, CO₂ emissions [16], and pollution [17], exploit environmental conservation, and minimize power usage [16].

As a result of green ICT technologies, the green IoT becomes more efficient, reducing energy consumption, hazardous emissions, resource usage, and pollution. As a result, Green IoT aids in the preservation of natural resources, cost reduction, and decrease of technology's negative impact on the environment and human health. As a result, green IoT focuses on environmentally friendly production, usage, design, and disposal. [17].

- Green computing: conserving energy while using computers and other information systems in an environmentally responsible manner.
- Reusing and recycling obsolete computers and other electronic equipment, as well as recycling discarded computers and other electronic equipment.
- Green IoT sound components, computers, and servers, as well as cooling equipment, are designed to be energy efficient.
- Environmentally friendly manufacturing: producing electronic components, computers, and other associated subsystems with little or no negative influence on the environment.

IV. COMPONENTS OF GREEN IOT

Green IoT mainly has communication technologies like Green RFID [19], Green WSN [20], Green CC [21], Green M2M[22], Green DC[23]. CC is for cloud computing, M2M is for machine to machine and DC is Data Centres.

- i. Internet technologies that are environmentally friendly Green Internet Technologies necessitates the use of customized hardware and software that are specifically intended to spend less energy while maximizing resource utilization.
- ii. RFID Tags in Green RFID tags can store modest amounts of data or information for any objects with which they are associated. RFID transmission requires RFID systems to be within a few metres of each other. Active RFID tags have built-in batteries that allow them to continuously transmit their own signal, whereas passive RFID

tags do not. They store the reader's vitality. Reducing the size of an RFID tag can aid in the reduction of non-biodegradable waste.

- iii. Environmental Wireless Sensor Network Although the WSN has a high number of sensor nodes, they are all low-powered and have limited storage. Green WSN can be achieved by employing techniques such as energy saving, radio optimization, green routing strategies that reduce mobility energy consumption, and smart data algorithms that reduce storage capacity and data size. Sensors should be engaged only when they are required.
- iv. Environmentally Conscious Cloud Computing Cloud computing offers services such as IaaS, PaaS, and SaaS, as we all know. In order to reduce energy usage, green hardware and software must be used in conjunction with a green strategy. Policies that are energy efficient must be implemented. Communication and networking technologies based on the Green Cloud Computing Scheme will also be deployed.
- v. DC against (green) Data centres are responsible for storing, preserving, processing, and disseminating a variety of data and applications. In the design of data centres, renewable energy sources should be used. Aside from that, routing protocols should be designed to be energy aware, to turn off idle network devices, and to incorporate energy characteristics into packet routing.
- vi. Green M2M Because M2M communication involves a large number of machines, efficient transmission power and communication protocols, as well as routing algorithms, are required. Check passive nodes should be present in order to save energy.

V. APPLICATION OF GREEN IOT

Significant changes in our settings have occurred as a result of IoT advances, and more changes may be forthcoming. The cost of improvements, however, might be huge due to the rise in e-waste, toxic emissions, and energy demand. Green IoT is projected to have a substantial impact on our lives in the future and contribute to a more environmentally friendly world. In the near future, we will see many devices, machines, sensors, drones, and other objects that work and interact with one another to intelligently complete tasks for the green environment in our daily lives. As a result, green IoT applications have focused on energy conservation, CO₂ emissions reduction, and pollution reduction.

Green IoT helps IoT explore new energy sources, is environmentally benign, and reduces the impact IoT causes to the environment. As a result, the diverse applications of green IoT are significant in terms of economic, environmental, and social sustainability, as well as the preservation of natural resources and the improvement of human health. The details application area, findings etc. of green IoT are presented in Table 1.

Table 1 Application area of Green IoT

Sl. No.	Application Area	Findings	Author/Reference
1.	Smart Home	Channel allocated optimization has been used to build a model for desired QoS provisioning of heterogeneous IoT devices in a smart home.	S. Aslam et. al. [24]
2.	Industrial Automation	Industries have been automated with devices that can do the work completely automatically without or with little operator interaction.	N. Kulkarni and S. Abhang, [25]
3.	Smart Health Care	Hardware and software are integrated in a Smart Health Care system. Sensors and microcontrollers are included in the hardware, while the cloud system is the software component to perform data gathering, data monitoring, data storage, and data management.	Z.M. Kalarthi [26]
		An intelligent collaborative security model to reduce security risk has been developed to discuss various innovations such as big data, ambient intelligence, and wearables can be leveraged in the health care context; examines various IoT and eHealth policies and regulations around the world.	S.R. Islam et.al. [27]

		The role of the Internet of Things in healthcare delivery, examining the technological factors that make it possible as well as the potential and challenges are focused here.	D. Niewolny [28]
		A Semantic Interoperability Model for Big-data in IoT (SIMB IoT) to provide semantic interoperability between heterogeneous IoT devices in the health-care domain is discussed. The concept is suggested for medicine with side effects based on data obtained from a variety of IoT devices.	F. Ullah et al. [29]
4.	Smart Grid	This study highlights the use of communication sensor networks in IoT and smart grid applications.	H. Yanti et al. [30]
		Yang et al. projected a low-cost remote memory substantiation for the smart grid.	Yang et al. [31]
		Liu et al. projected some approaches to upsurge data validity of IoT level data damage for smart cities.	Liu et al. [32]
		The impending smart grid can measure and share energy consumption and build full energy systems.	S. Karnouskos [33]
5.	Smart Cities	Smart cities represents one of the most promising and prominent IoT application.	R. Petrolo et.al. [34,35]
		IoT can be advocated the machines that provided with extra sensory and communication add-ons in order to make the environment smarter. In a metropolis, machines, it can perceive the surroundings and communicate with one another.	P. Sathyamoorthy et. al. [36]
		Smart parking, smart light lamps, high-quality air, smart vehicles, smart traffic management, and so on are examples of smart cities.	P. Ramaswamy [37], M. Popa [38], A.M. Vegni et. al. [39], K. Su et. al. [40]
		The key to innovative technology and Big data success in smart cities, where the quality of life will be improved while pollution is reduced.	M. Maksimovic [41]
		The concept of smart cities has evolved into smart and linked communities.	Y. Sun et.al. [42]
		Address the principles and applications of smart cities.	H. Song et. al. [43], D. Jiang et. al. [44]
6.	Smart Agriculture	In healthcare and agriculture, the combination of IoT and CC helps to lower the power consumption of the CC and IoT combo.	C.S. Nandyala [45]
		Green IoT and green nanotechnology appear to be viable options for developing smart and sustainable agriculture and food production.	M. Maksimovici and E. Omanovic-Miklicanin, [46]

VI. TECHNIQUES OF GREEN IOT

Green IoT techniques based on software

For example, data centres can be critical in developing an energy-efficient IoT network. An Orchestration Agent (OA) in a Client-Server model system is responsible for data centre management in the e-CAB system, which is a policy-

based design established by a researcher in [47]. [48] Proposes a context aware sensing platform (C-MOSDEN) that uses selective sensors to achieve energy efficiency, resulting in decreased energy consumption and minimal overheads.

Green IoT techniques based on hardware

Many IoT energy consumption models focus on hardware improvements, but categorizing things in an IoT system might help create a green network. [50] Describes the evolution of passive RFID, while [49] investigates the advancement of active RFID. As mentioned in [51], the Wireless Identification and Sensing Platform (WISP) can lead to a more energy efficient IoT system.

Green IoT techniques based on policies

Strategies and restrictions based on real-time data gathered from IoT devices can help preserve energy. The steps of planning methods for achieving energy efficiency include supervision, information management, user input, and system automation. Automation of equipment can help detect a resident's location within a building for energy saving considerations.

VII. CHALLENGES AND FUTURE RESEARCH DIRECTIONS

Despite significant research efforts, green IoT technology is still in its early stages. There are numerous hurdles and challenges that must be overcome. The following are the major challenges:

- Integrate energy efficiency across the IoT infrastructure to achieve acceptable performance.
- To lessen environmental impact, green applications should be employed.
- Green IoT reliability and energy consumption models
- A context-aware IoT system that saves energy.
- The communication equipment and protocols used should be low-power and energy-efficient.
- The complexity of green IoT infrastructure is being decreased.
- Effective dynamic spectrum sensing and effective spectrum management are mutually exclusive.
- To make IoT a realistic choice, efficient energy techniques such as wind, solar, vibration, and thermal are required.
- Efficient cloud management in terms of energy usage; • Efficient security methods, such as encryption and command commands.

VIII. CONCLUSION

With increase in the use of number of devices at a time the energy consumption and reliable communication becomes the serious issue. In this paper, we present the architecture of IoT, the green IoT technology was described in this study. The study discusses the motivations, challenges, components, application and benefits of green IoT. It also looked at the green IoT life cycle and the technologies needed to establish a green IoT system. The role of the Internet of Things in 5G and smart cities is also discussed. In addition, future research directions and challenges are discussed.

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