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Green IoT: Need, Application, and Challenges

[1]Rana M Pir

[1]Assistant Professor
[1]Computer Science and Engineering,
[1]Leading University, Sylhet, Bangladesh

Abstract: IoT is an important step toward the upcoming smart era. Most devices are connected to the internet nowadays. IoT utilizes sensor data and interconnected devices to transfer information from one device to another using internet. IoT has numerous advantages, but the only disadvantage is that all the connected devices should remain on all the time to give and sense the data, which over in all consumes lots of energy. Green IoT is the concept of saving energy using various green computing techniques in IoT devices. This paper introduces GreenIoT and explains the need for Green IoT in today's era.
Moreover, this paper focuses on various applications of the Green IoT. It also provides the research path in the area of GreenIoT. Finally, it discusses open challenges in Green IoT with some of the solutions and research trends in the area.

***IndexTerms* – IoT, Green IoT, Smart devices, IoT Devices, Green computing**

1. INTRODUCTION

The increase in energy usage and the integration of renewable energy are crucial accelerators of climate change and sustainable energy transitions. The Internet of Things (IoT) is expanding rapidly. Its network architecture consists of numerous appliances, such as actuators, sensors, and other hardware embedded devices with the system's information-sensing, -processing, and -communication capabilities. The Internet of Things (IoT), a recent innovation, has many uses in the energy industry, specifically in supply and demand, transmission, and distribution. Many types of sensor equipment, processing components, and communication technologies exist. Engaged in any IoT-based system's development and advancement. A large number of sensor devices, The creation and evolution of processing components, communication technologies, and any system based on IoT, even if batteries power sensors and processing equipment, must be efficient in delivering top-notch results. Additionally, the communication tools must ensure a constant connection for the system's QoS. Resulting of IoT, tangible items are individuals who are effortlessly included in the information network, where they may participate actively.

So permitting the exchange of information about their state, surrounding procedures for the environment, production, and maintenance with scheduling, among many other things. However, Numerous serious problems still need to be resolved, and social and technological snags must be untangled before the Internet of Things becomes a reality. The major challenges are to complete everything. For example, the ability of linked devices to communicate with one another and how to provide them with a high level of smarts by permitting their conduct and maintaining the consumers' privacy and security in a [2]. Their data, In contrast, increased ecological knowledge, higher energy prices, and shifting consumer preferences toward greener goods have empowered consumers to make spontaneous decisions to buy environmentally friendly items. Their key focuses are energy-efficient production methods and green manufacturing [3].

Thus, An IoT system's focus on energy efficiency is more necessary. This document includes the current researchers' efforts to create energy-efficient IoT systems that will be functioning and discussed. Effective energy use is one of the Sustainable Development Goals [4] set forth by the United Nations. Important factors for long-term and permanent growth. Additionally, energy efficiency benefits the economy by lowering the cost of fuel supply and its imports, energy production, and decreasing emissions from the energy industry. A convincing study of the real-time data demonstrates improved energy management and increased energy efficiency. Therefore, the importance of data in the energy supply chain is crucial [5].

IoT is an energy-efficient technology (hardware or software). It refers to energy-efficient inter-connected equipment to minimize CO2 emissions, greenhouse gas emissions, and power usage by utilizing energy-efficient computing devices, communication protocols, and network-based designs that make the best use of available bandwidth. Therefore, sustainable design and energy-efficient construction are crucial components of the Green IoT.

2. Need for Green IoT

The Internet of Things (IoT) is a system of cameras, smart sensors, databases, software, and data centers that form a worldwide, invisible, immersive, ambient communication network and computing environment [7]. The research in [8] used the IoT concept to create a green campus environment emphasizing energy conservation. Despite earlier support provided in [8], IoT components were covered in [2], where the benefits of IoT architecture addressing how to establish a green campus by making smart and effective use of sophisticated technologies were outlined.

The authors of [9] proposed distinct technical paths that may be taken to realize a future green internet. Green IoT focuses on lowering IoT energy consumption, which is essential for realizing the smart world's vision of sustainability through intelligent things while also lowering CO2 emissions. Designing and using components make up green IoT. As seen in Fig. 1, creating computer hardware, communication protocols, energy efficiency, and networking topologies are examples of "green IoT design aspects" [15]. Utilizing IoT technology helps cut down on or completely stop CO2 emissions and other types of pollution and energy waste. Despite earlier data, Uddin et al. [10] offered methods for improving energy efficiency and lowering CO2 to enable green information technology.

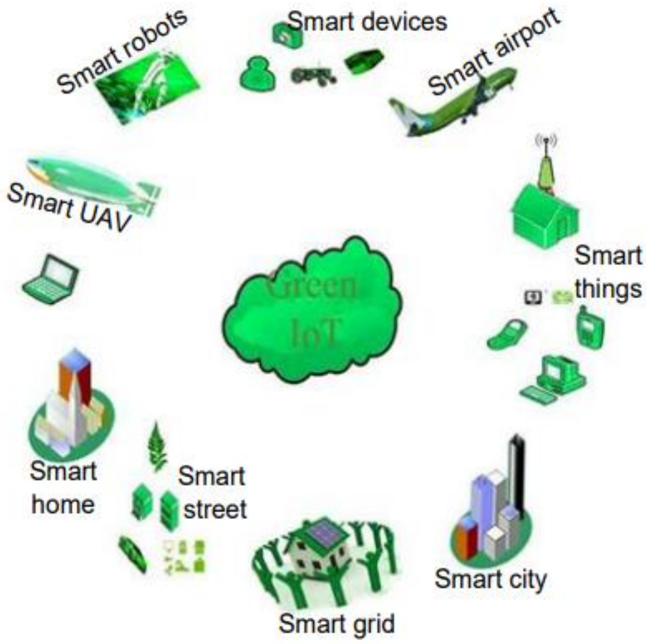

Figure 1: GreenIoT [18]

M2M devices include sensors and connectivity add-ons so they can talk to one another and detect their surroundings. Sensors will use much electricity to do the duties. In networking, green IoT seeks to locate the relay and determine the number of nodes satisfying energy-saving and financial limitations. Therefore, green IoT is essential for implementing IoT to reduce energy consumption [5, CO2 emission [11], pollution [12–14], take advantage of environmental conservation [15], and minimize power consumption [11].

The green IoT is described by Murugesan as "the study and practice of designing, using, manufacturing, and disposing of servers, computers, and associated subsystems such as monitors, storage devices, printers, and communication network systems efficiently and effectively with little to no impact on the environment" in [16]. Three principles comprise the green internet of things: design technologies, leverage technologies, and enabling technologies. Communication protocols, network topologies, device energy efficiency, and interconnections are all examples of design technology.

Technologies that "leverage" resources reduce carbon emissions and improve energy efficiency. Green IoT is made more effective by reducing energy use, toxic emissions, resource consumption, and pollution due to green ICT technology.

As a result, Green IoT helps dramatically cut costs, minimize the impact of technology on the environment and human health, and preserve natural resources. Furthermore, green IoT emphasizes environmentally friendly production, use, design, and disposal [28].

1. Green use: utilizing computers and other information systems ecologically friendly while reducing their power usage.
2. Green Disposal: Recycling unused computers and other electronic equipment is another environmentally friendly disposal method.
3. Green Design: Energy-efficient computer, server, and cooling equipment design is another aspect of green design.
4. Green Manufacturing: Environmentally friendly manufacturing: creating computers, electronic components, and other related subsystems with little to no environmental effect.

Reducing energy utilization and using renewable energy sources instead of traditional mechanisms is the main motive of GreenIot technologies.

3. Applications

IoT can be used in various fields, as shown in Fig. 2. GreenIoT is not a new technology to IoT, but in simple words, it can be said as GreenIot is nothing but IoT with energy-saving. Thus, it is useful in all areas where IoT can be used.

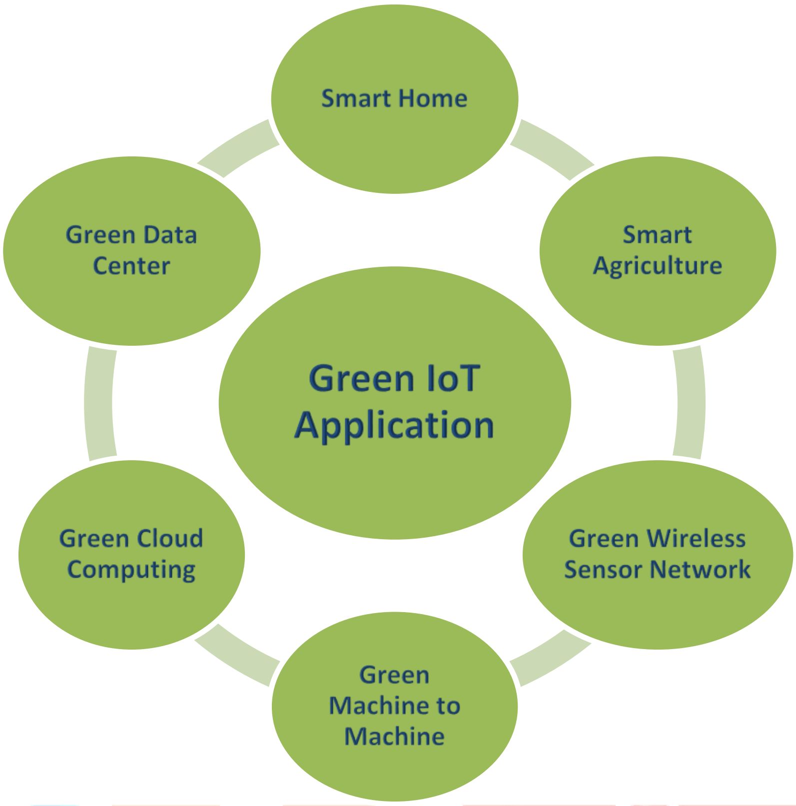

Figure 2: Green IoT Applications

a. Smart Home

A green IoT offers remote control of a home's electrical, heating, and lighting fixtures from a computer or smartphone[18]. Voice instructions are recognized by the main mobile/computer in the building. The T.V., computer, and phone combined into one gadget recognize residents for tailored actions, replies, etc. To lessen the influence on the environment, it is important to address the life cycle of green IoT, which includes green design, green use, manufacture, and lastly, green disposal/recycling. Aslam et al. approach is for desired QoS provisioning of heterogeneous IoT devices in a smart home using channels allotted optimization.

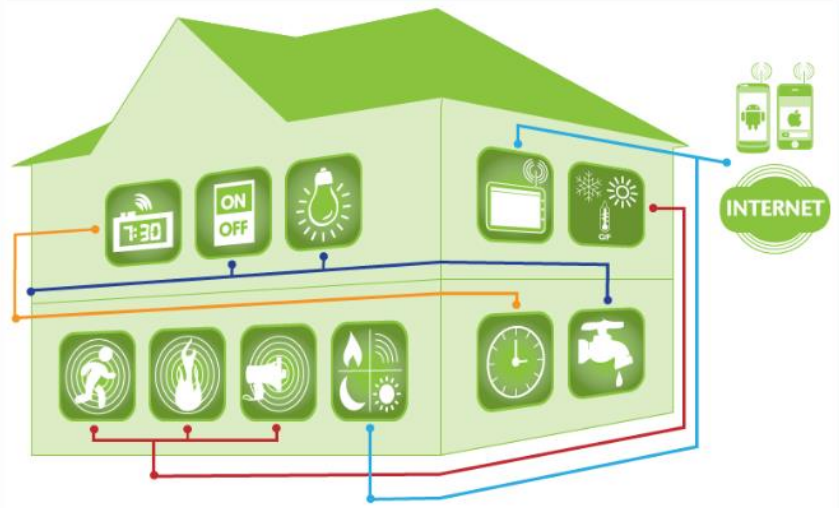

Figure 3: Smart Home[20]

b. Smart Agriculture

It will allow the farmers to overcome the significant obstacles they encounter. The sector should consider methods and tactics for managing costs, limiting land availability, and coping with water shortages.

Agriculture-related green IoT applications were presented by Nandyala et al. [22]. The integration of IoT CC and IoT in agricultural and healthcare systems. To develop an intelligent and sustainable agricultural and food sector, green IoT and green nanotechnology appear to be the appropriate alternatives.

Figure 4: Smart Agriculture [21]

c. Green Wireless Network

The wireless sensor networks were created due to combining wireless communication with sensing (WSNs). WSNs stand for the essential technology that has enabled the growth of IoT. A sensor comprises many tiny, inexpensive, low-power electronic components [23]. The elements of WSN are represented by a sizable number of sensors and base station (B.S.) nodes. The sensing, power, processing, and communication units that make up each sensor node were covered in [23]. Worldwide, sensor nodes are being set up to monitor regional and global environmental variables, including weather, pollution, agricultural fields, and others. Each sensor node gathers information from the environment, including temperature, sound, pressure, humidity, acceleration, etc. Using ad-hoc technology, sensors may also talk with one another and provide the necessary sensory data to B.S. However, they are not authoritative and have the minimal processing power, limited power, and little storage. A BS node is.

WSNs are used for a variety of purposes, including fire detection [24–26], object tracking [27–29], environmental monitoring [23, 30–32], adapting to changing military requirements [33], control machine health monitoring, and monitoring industrial processes [23].

Studies in [34, 35], which call for putting sensor nodes in sleep mode for most of their lives to save energy, as illustrated in Fig. 5, support the notion of a green IoT. When data transfer happens at extremely low power, WSNs can justifiably be implemented. Sensors may use environmental energy such as sunlight, vibrations, kinetic energy, temperature differences, etc. [36–38]. WSN technology must transmit a signal effectively and provide sleep mode for reduced power consumption. Furthermore, sensor microprocessors must be able to wake and sleep intelligently. Decreased energy consumption and increased processing speed are thus key trends for WSNs. Green WSN is a developing idea aiming to reduce CO_2 emissions while maximizing lifetime and throughput performance. WSN's objective is to provide enough energy to lengthen system lifespan and contribute to reliable/robust transmission without lowering the overall Quality of Service (QoS).

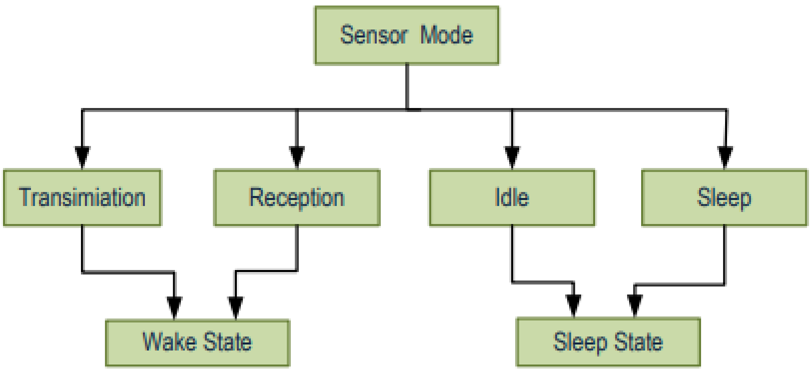

Figure 5: Sensor modes for Green IoT[18]

For greenhouse control and environmental monitoring, sensors are required [23]. They should also utilize distributed clustering to create a dispersed form that spreads across the greenhouse.

The strategies listed below might be used concerning green WSN technology [5, 22]:

i. Energy depletion (e.g., wireless charging, utilizing energy harvesting mechanisms that generate power from the environment such as the sun, vibrations, kinetic energy, temperature, etc.);
ii. Optimization of radio techniques (e.g., transmission power control, cooperative communication, modulation optimization, energy efficiency);
iii. Sensor nodes should only operate when necessary and spend the rest of their lives in a sleep mode.

d. Green Machine to Machine

Machines may now acquire data without human interaction as they have become smarter recently. The driving force behind the development of many modern technologies is artificial intelligence (A.I.).

To be deployed on a sizable scale, the concept of intelligent machine-to-machine (M2M) communication must be successful. For example, machines need to have robust connections to improve the efficiency of modern computers and other electronic devices for storing enormous amounts of data. They may then share the capacity with all nearby machines and physical machines. As depicted in Fig. 6, machine represents an item with electrical, mechanical, environmental, and electronic qualities. The advantage of such built-in radio communication is that it ensures M2M communication is secure and effective for various jobs, including domestic, commercial, industrial, and medical procedures.

Massive M2M nodes intelligently communicate, gather data, and transfer it to B.S. to deploy the M2M domain for wireless network relays. The BS further supports numerous M2M network-based applications in the application area. Massive machines are used inM2M communications and green M2M. They will use great energy, especially in the M2M industry. The M2M communication challenges for the home energy management system (HEMS) in the smart grid were examined by Niyato et al. [85]. Several of the methods listed below might be utilized to improve energy efficiency for "greening" IoT [5]:

Utilize energy harvesting and the advantages of C.R. a) Intelligently adjust power transmission. b) Efficient communication protocols needed for distributing the computing techniques. c) Activity scheduling of nodes used to switch some nodes to sleeping mode while maintaining the functionality of the original network.

C.R. is a network that combines computer networks and electrical networks. It provides intelligent M2M communication between remote-area power management and CR-based smart meters (RAPM). The purpose of the combination is to increase spectrum efficiency and power efficiency of energy distribution. Additionally, Vo et al. [18] described the converged network architecture based on the adaptable, high-capacity, and economically viable 4G LTE technology, which facilitates end-to-end (E2E) M2M communication.

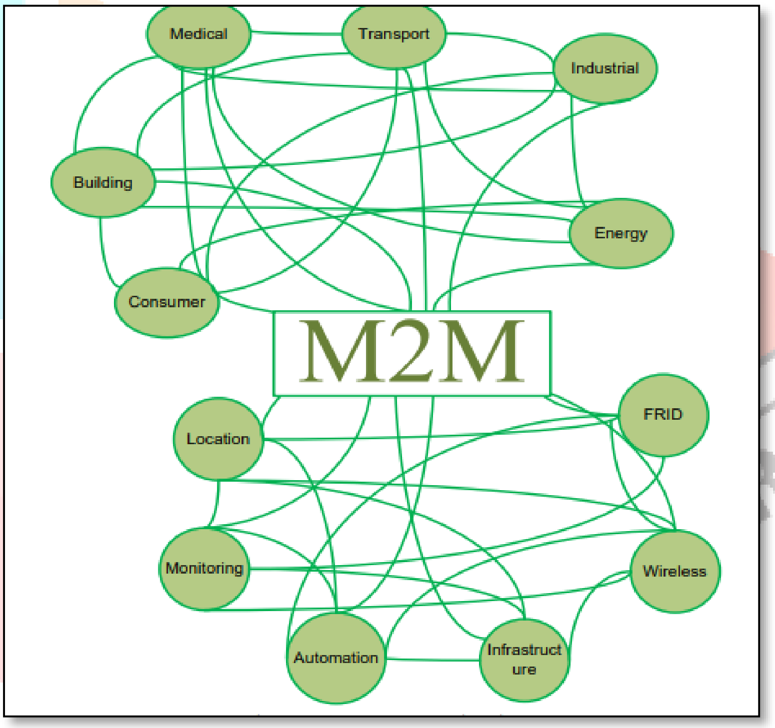

Figure 6: M2M Computing [18]

e. Green Cloud Computing

A new virtualization technology utilized on the internet is cloud computing (CC). As conceptually depicted in Fig. 6, it offers limitless computing, limitless storage, and service delivery over the internet. IoT is prevalent, but CC technology is pervasive. Much study is being done on the combination of CC and IoT. The main goal of GCC is to encourage the adoption of environmentally friendly, easily recyclable, and reusable items. Shuja et al. [39] . 's concept of green computing with an emphasis on information technology was thus given. Baccarelli et al. [40] 's discussion of the green economic IoT solution over the already-existing Fog-supported network is also noteworthy.

GCC's main goals are minimizing hazardous materials, increasing energy usage, and improving the capacity to recycle garbage and outdated items. Additionally, it may be accomplished through resource allocation for product life, paperless virtualization, and effective power management. Research in [28], which discusses the different solutions for GCC by lowering energy use, lends credence to the theory.

The integration of CC with IoT in various applications, architectures, protocols, service models, database technologies, sensors, and algorithms was also thoroughly covered by Sivakumar et al. in their article [41]. Additionally, Zhu et al. [42] suggested a multi-method data delivery (MMDD) for users of the sensor cloud (S.C.) that resulted in cheaper costs and shorter delivery times. Delivery from WSN to S.C. users, delivery from the cloud to S.C. users, delivery from a cloudlet to S.C. users, and delivery from S.C. users to S.C. users are all included in MMDD.

Figure 7: Green Cloud Computing [18]

Despite the various studies [5, 22,43] that were conducted on the GCC and offered prospective remedies, it can be shown that:

i. Using hardware and software to reduce energy usage
ii. Power-saving methods utilize virtual machine (V.M.) technology (such as V.M. consolidation, V.M. migration, V.M. placement, and V.M. allocation).
iii. A variety of methods for allocating resources that are energy-efficient and associated work.
iv. Effective techniques for energy-saving devices.
v. Green's CC methods are built on technology enabling clouds, such as networks and communications.

f. Green Data Center

A novel technology for data management, storage, and distribution is the "Green Data Center" (GDC). Users, systems, objects, and other entities produce this data. Data centers (D.C.s), which handle various data and applications, have substantial running costs and CO2 footprints. Additionally, big data production is increasing due to numerous everyday items like mobile devices, sensors, etc. Therefore, the need for D.C.'s energy efficiency is growing as we move toward a smarter world [5]. Numerous strategies were explored by authors in [43] that improved the energy consumption and prediction for D.C.s and their constituent parts. Authors in [44] offered an optimization approach for the energy efficiency of D.C. with supporting QoS in addition to the work of [43] authors. Additionally, GDCs offer data services for 5G's MANETs (mobile ad hoc networks helped by the cloud) [44].

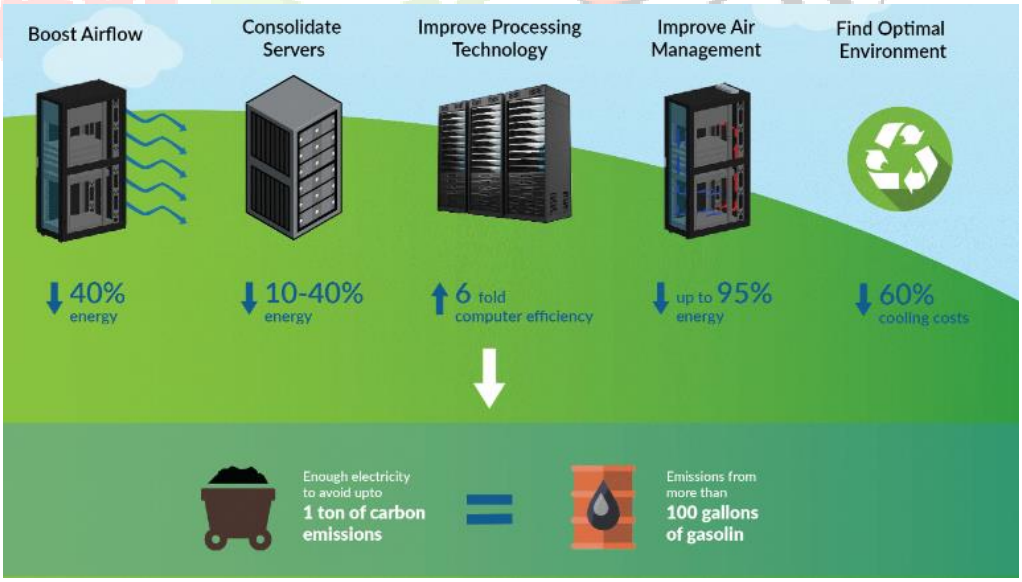

Figure 8: Green Data Center [19]

The following features [5, 82, 96] can be leveraged to increase energy efficiency for GDC in many different ways. Use renewable or environmentally friendly energy sources,

i. employ dynamic power management techniques that are effective, and
ii. develop technology that is more energy-efficient.
iii. Create innovative energy-efficient data center structures to conserve power;
iv. Create accurate and efficient data center power models, and
v. Utilize communication and computing approaches.

4. Future Trends

In the future, people will have access to eco-friendly solutions thanks to the combination of sensors, IoT devices, connections to 5G networks, and the powerful backing of A.I. This suggests green forms of communication between people and things as well as between themselves as IoT devices will also be context-aware and capable of performing certain tasks. Green IoT will become more well-known soon due to the increase in power throughout the design phase. In reality, IoT devices should employ routing algorithms while exchanging data and go to sleep when not in use.

Green IoT now focuses on various technologies, including green RFID, green wireless sensor networks, green cloud computing, machine to machine, green data centers, green communication, and green internet technologies. If the following advancements are accomplished, the potential of Green IoT will increase in the future:

i. IoT application items require more study to cut CO2 emissions and conserve energy.
ii. To create an energy balance and enable green communication between IoT devices, R.F. energy collecting should be considered.
iii. Identifying new and alternative resources while reducing energy consumption in IoT devices is important to make them appealing.
iv. Finding the best technological approaches to improve bandwidth, throughput, and delay QoS metrics can efficiently and effectively help to green IoT.
v. M2M connectivity is essential for cutting energy use. The ability to automate operations requires smarter machines. Machine automation delays must be kept to a minimum when immediate action is required.
vi. Data from the sensor might be transferred to a mobile cloud, which would be more advantageous. Sensor-cloud combines the mobile cloud and wireless sensor network. This cutting-edge technology has enormous potential for green IoT. For example, a green social network as a service might look at the system, service, WSN, and cloud administration's energy efficiency (SNaaS).
vii. Future IoT gadgets will be replaced by UAVs, reducing power usage and environmental pollution. In addition, UAVs can potentially be low-cost, highly effective green IoT devices.
viii. Major technological considerations for IoT devices and apps include end users' simplicity of installation and usage.
ix. Sensors usually experience quick energy depletion due to their continual detection. To conserve energy, a variety of sleeping techniques have been proposed in the past. However, future study is necessary since extrapolating from historical data can result in considerable energy savings for sensors.
x. Data and awareness of context. Unnecessarily using many resources is the process of gathering data without context. Preserving data context so that further data processing makes more sense will be one of the hardest tasks in the future.
xi. Uninterrupted connection. There will be greater competition for available spectrum as well as increased interference as the market for IoT devices expands. Future IoT devices need to be able to operate in interference-prone environments and effectively decrease interference from other IoT devices while using little resources.

5. Conclusion

The 21st century's rapid technological advancement has several benefits. However, as technology advances, there is a higher need for energy, which is also intentional e-waste and harmful emissions. This paper reviews and categorizes the most important technologies for a green IoT and maintaining a smart and eco-friendly society and environment. The ICT revolution has significantly improved the ability to green IoT, including WSN, M2M, communication networks, the Internet, DC, and CC. Based on the key ICT technologies, the things around us will develop the intelligence to carry out specific tasks independently. It will result in a new kind of green communication between people and things and among things, where bandwidth utilization is optimized, hazardous emissions are minimized, and power consumption is optimally reduced. Future recommendations for successfully and efficiently enhancing green IoT-based applications have been mentioned. This study offers insightful information for anybody looking to learn about green IoT research.

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