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Green IoT: Sustainability Environment and Technologies

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Abstract

The Internet of Things (IoT) connects everyone in the smart world, so the energy consumption of IoT technology is a challenging and attractive research area. The development of technology in the field of IoT has changed the way of life and enriched society with its benefits, but we must not ignore the fact that IoT consumes energy, contributes to toxic pollution, and generates electrical waste. To increase the benefits and reduce the harmfulness of IoT, there are increasing tendencies to move towards green IoT (G-IoT). The G-IoT is considered the future environmentally friendly IoT. Greening ICT technology plays a key role in G-IoT and promises many benefits to society such as efficient production, and reducing the energy used to design and distribute ICT devices and equipment. This paper will present a comprehensive overview of G-IoT technologies and strategies that demonstrate work and efforts to build a green and smart world, contributing to a safe and healthy environment, smart and high quality of life based on enabling technologies, reducing pollution, and reducing energy consumption. ICT technologies that enable G-IoT include Green RFID, Green Wireless Sensor Network (GWSN), Green Cloud Computing (GCC), Green M2M (G-M2M), and Green Data Center (GDC). The paper will also present an analysis of the importance of environmental technology processes in sustainable development, exploring the principles and roles of G-IoT in the progress of society through examining its potential for improving quality of life, environment, economic growth, and green global modernization.

Keywords: *Green Internet of Things, Green Technologies, Sustainability, Energy saving*

1 Introduction

Technology can help realize the vision of a sustainable world only if "correct" decisions about technological innovations are made at an early stage of their development. In this way, technologies are becoming indispensable tool for sustainable development because they can be used as a means to ensure that people have access to clean water and clean and affordable energy, live in less toxic environments, manage natural resources more efficiently and effectively and have efficient regimes. In recent years, many citizens have begun to accept the trend of "living green," which includes smart use of e-m and m-services, teleconferencing, the use of green IT tools and services over the Internet, especially G-IoT (Green IoT), expanded use of environmentally friendly products, green construction, green roofs, the use of renewable energy sources, energy savings at home, awareness of the importance of recycling, etc. Thus, environmental technologies and the move towards G-IoT enable the realization of the benefits offered by new technologies, while minimizing the impact on the environment and energy consumption. After numerous discussions by some authors on green ICT and green IoT, in general, are based on green communication technologies and green smart grids, the conclusion is that the technologies that make up green ICT are: Green RFID, Green wireless sensor network, Green cloud computing, Green M2M, Green Data Center.

Information and communication technologies are ingrained in our daily lives that it would be difficult to sustain a society without them. Many things need a great focus in the areas of standardization, security, and governance for the smooth functioning of the Internet of Things that can benefit society as a whole. Green technologies will play an important role in enabling energy-efficient IoT. Many challenging issues need to be addressed. Green IoT is a promising technology that will drastically improve the quality of life in smart cities and change our environment to be smarter, healthier, greener, and more economically sustainable. Today, the most exciting areas focus on environmental issues such as green communication and networking, green design and implementation, green IoT services and applications, energy-saving strategies, integrated RFID and sensor

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networks, mobility and network management, a collaboration of homogeneous and heterogeneous smart grid networks and green localization [1]. To develop optimal and efficient solutions for greening IoT, it is necessary to explore certain areas that would contribute to the same. To gain as much insight as possible into the principles of G-IoT and its role in sustainable development, it is necessary to explore the ideas, significance, and current impacts of G-IoT innovation in a way toward a sustainable smart world. With a G-IoT vision, developing products and services that have minimal or no impact on human health and harm the environment, minimizing energy consumption, pollution, and emissions, and conserving natural resources, the world has the potential to become a more environmentally conscious and sustainable place to live [2].

2 Definitions of Green IoT (G-IoT)

Taking various measures to conserve environmental resources, reduce the carbon footprint and promote efficient energy consumption techniques is one of the reasons for switching to Green IoT. According to [3], Green IoT focuses on reducing energy use for IoT, as a necessity to fulfill the idea of a smart world and sustainability of intelligence of everything, as well as reducing CO2 emissions.

Elements of green IoT design relate to the development of computing devices, communication protocols, energy efficiency, and network architectures. Green IoT in [4] is defined 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 minimal or no impact on Environment."

Due to development of green ICT technologies, green IoT is becoming more efficient through hazardous emissions, reduced resource consumption, and reduced pollution. Consequently, Green IoT leads to the conservation of natural resources, minimizing the impact of technology on the environment and human health and significantly reducing costs. Therefore, green IoT focuses on green production, green use, green design, and green disposal [1].

3 Enabling G-IoT Technologies

Advances in technology in the field of IoT have changed the way of life, enriching society with its advantages. It is important to emphasize and not ignore the fact that IoT consumes energy, contributing to toxic pollution and the generation of electrical waste. Green technologies refer to the development of energy-efficient technologies that include computer and communication technologies. These technologies mean lower energy consumption through more efficient use of available green infrastructure. After numerous discussions by several authors about what green IoT based on green communication technologies and green smart grids involves, it is concluded that the technologies that make up green ICT are listed and presented in Figure 1.

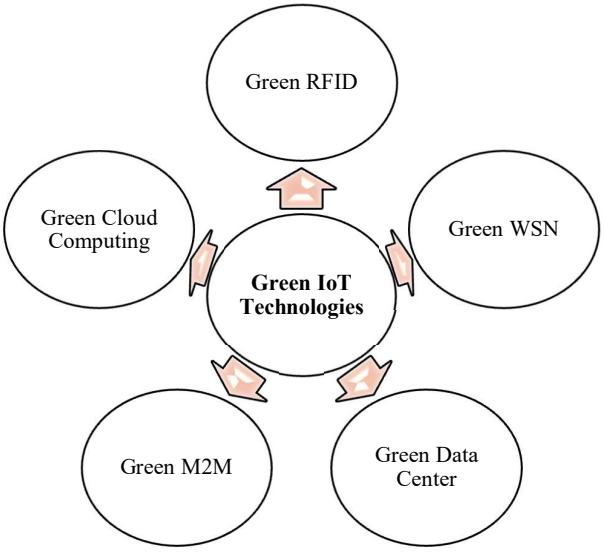

Figure 1. Green IoT Technologies

In the continuation of the chapter, the technologies that enable green IoT will be briefly explained with an overview of green strategies and mechanisms for G-IoT.

3.1 Green RFID

RFID technologies have become widely accepted in many important application domains, such as logistics, warehousing, retail, public urban transportation, and security. The purpose of RFID tags is to store information about the objects to which they are attached. The basic procedure is that the RFID tag reader initiates the flow of information by transmitting a signal query, followed by the response of nearby RFID tags [5].

Environmentally friendly RFID tags are suitable paper-based cartridges reducing the use of PET-based products. Labels are produced on renewable paper but without plastic layers and harmful chemicals. Since the antenna is designed in an innovative laser production process, all excess aluminum is completely recycled, and the paper used can be mixed with the pulp in the production of the new paper. The advantages of FRID include a standardized and scalable approach, which is reliable and cost-effective.

3.2 Green Wireless Sensor Networks (GWSN)

Green Wireless Sensor Networks (GWSN) is a concept in which lifetime and bandwidth-related characteristics are maximized while minimizing the carbon footprint effect. These networks are among the most natural applications of energy collection techniques. Sensor nodes are usually placed in wide areas where human intervention is demanding, so their lifespan is limited by the life of their batteries.

The idea of green IoT in wireless sensor networks (WSNs) is to keep the sensor in sleep mode for most of its life to save energy. Numerous authors have proposed their ideas for greening sensor networks by presenting a hierarchical network design that enables energy-efficient and flexible IoT, then a cooperative approach to save energy and enable longer battery life, focusing on extending network life and increasing energy efficiency [6]-[8].

3.3 Green Cloud Computing (GCC)

Cloud computing (CC) is a technology that enables unlimited computing, storage, and provision of services over the Internet. Cloud computing and green computing are the two most popular areas of information and communication technologies with numerous applications worldwide.

The primary goal of Green Cloud Computing (GCC) is to promote the use of environmentally friendly products that are easy to recycle and reuse. GCC is a resource-efficient model, and its most important feature is that it is environmentally friendly, energy-efficient, and virtualized [9]. The idea of Green Cloud Computing is further explored using various techniques and principles to reduce energy requirements, analyzing important aspects of GCC energy efficiency.

3.4 Green Machine to Machine (G-M2M)

The term Machine to Machine (M2M) refers to the exchange of data between two or more entities, objects, or machines that do not require human interaction. For the realization of green M2M, various techniques for reducing energy consumption and increasing energy efficiency are proposed, such as Mobile Edge Computing, Local Computing, Energy Consumption Model, and other Solutions to Energy Consumption in Green M2M Communications [10], [11].

3.5 Green Data Center (GDC)

Green Data Center (GDC) is a technology and storage facility for data storage, management, and dissemination. Green data centers use energy-efficient technologies. With the increase in the number of Internet users, energy consumption in data centers has significantly increased.

Looking into the IT system, one of the solutions that may reduce the energy consumption in the data center is to adopt the GDC using green computing to solve the issues such as high energy consumption and low utilization rate of equipment [12].

To balance the global carbon footprint, paper [13] presents an energy model dedicated to future GDC. GDC aims to improve air handling and management technology, find the optimal environment, consolidate servers and increase airflow by taking into account reliability and performance, resource management, and energy management. These challenges are interlinked and need to be addressed by data center operators to improve energy efficiency and maintain performance.

Table 1. provides an overview of green technologies from the aspect of energy-saving mechanisms and their corresponding green strategies. In addition to the listed technologies that enable green IoT, it is important to mention the green Internet and green communication and networking. Green communication plays a crucial role in green IoT. The idea of a green communication network refers to low CO_2 emissions, low radiation exposure, and energy efficiency. Recently, the green internet has become a topic that many researchers are actively involved in. Internet technologies are used to develop smart and green networks. The idea of greening the internet is to reduce electricity consumption with increased efficiency.

The benefits of technologies that enable green IoT are numerous, but their greatest contribution is reflected in the reduction of energy consumption and its savings, as well as the reduction of carbon dioxide emissions, which directly affects climate change and reduces global pollution. From an economic point of view, the application of green technologies reduces costs and creates the potential for improving the quality of life, the environment, economic growth, and green global modernization.

The exchange of IoT in the real world is possible only through the cooperation of several technologies that enable it, which are implemented through green tags, sensors, and the Internet. Only the synergy of these green IoT providers can create future technologies that will contribute to a smart world and its greening.

Table 1. Green strategies and mechanisms for G-IoT

Enabling G-IoT technologies		
Green technologies	***Energy-saving mechanisms***	***Energy-saving strategies***
Green RFID *[10], [14]*	Existence of active tags and passive sensors	- Energy-efficient algorithms and protocols - Reducing the size of rfid tags due to recycling - Production of labels on recycled paper substrate
Green WSN *[6]-[8]*	- Reducing communication between nodes - Sleep mode	-Smart modes of operation through dynamic energy management strategies - New energy-efficient routing algorithms
Green Cloud Computing *[9], [10], [15], [16]*	- Creating hardware solutions aimed at producing devices that consume less energy. - Design of software solutions that consume less energy with minimal use of resources	- Usage of resources that are eco-friendly and maintain computing performance without degradation.
Green Machine to Machine (M2M) *[11], [17]*	- Common energy-saving mechanisms - Use of efficient communication protocols	- Group-based strategies - Low-mobility-based optimizations
Green Data Center *[13], [15], [18]*	- Energy efficiency - Use of renewable energy sources	- E-waste recycling - Low-emission building materials - Exclude unnecessary content - Minimizing data

4 Principles and Roles of G-IoT

This chapter examines the analysis of the importance of environmental technology processes in sustainable development, exploring the principles and roles of G-IoT in the progress of society through examining its potential to improve quality of life, environment, and green modernization globally.

Based on the evaluation of different technologies, techniques, strategies, and methods for the implementation of green IoT, appropriate principles can be identified to make IoT greener. Below are some of the principles regarding green IoT [10], [19]:

- the use of bioproducts in the production of G-IoT components and their environmental design;
- the use of renewable green energy sources such as solar energy, wind energy, water, oxygen, geothermal sources;
- Incorporate a security mechanism and data privacy into each component of the G-IoT system and the overall G-IoT system;
- Develop more efficient guidelines for reducing energy consumption in smart buildings. Policies can have a direct impact on energy consumption and as a result, a significant amount of energy can be saved;
- Reduce the size of the network by efficiently installing nodes and using appropriate routing mechanisms, which will result in high energy savings.

Through innovative G-IoT solutions, many transportation systems can become seamless, inclusive, affordable, secure, reliable, and robust. With a G-IoT vision, developing products and services that have minimal or no impact on human health and the environment, minimizing energy consumption, pollution and emissions, and conserving natural resources, the world has the potential to become more environmentally conscious and sustainable place to live [20].

5 G-IoT and Sustainable Environment

To achieve the goal of sustainable development, plans are developed at the national and international levels, taking into account environmental, social and economic aspects. The coming era of revolution is the green internet of things. The Green IoT aims to bring significant improvements to the environment and human well-being to make the world smarter by using sustainable technological development. Using technological advances in technologies that enable IoT, Green IoT has a great ability to strengthen environmental and economic sustainability. There is a great need and importance for

green technologies and green processes in sustainable development and building a smart world [21].

On the path of green IoT towards sustainable development, the focus is on technologies that adequately contribute to a sustainable environment through the generation of efficient energy conservation systems (Figure 2).

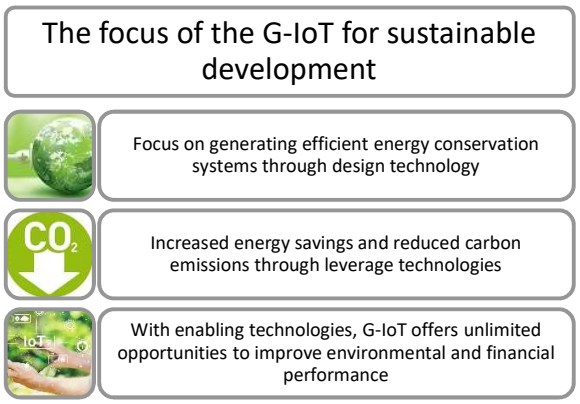

Figure 2. G-IoT focus on sustainable development

The main goal of sustainable development is to create and maintain a balance between the social, financial, and environmental requirements of society to enable the prosperity of present and future generations. The Green IoT aims to bring significant improvements to the environment and human well-being to make the world smarter by using sustainable technological development.

Any rapidly advancing technology has specific potential shortcomings that need to be carefully analyzed. Since IoT devices are measured in billions, it is necessary to solve certain challenges that have been discovered through certain research [21]. The main goal is to ensure sustainable and balanced development of IoT technologies, which is reflected in minimizing energy consumption in IoT devices, improving the recycling rate, and ensuring better e-waste management.

A special area of application that contributes to the development of green IoT refers to a smart and green environment. As we move towards green IoT, new resources should be sought, less energy consumed and the negative impact of IoT on environmental and human health impairments should be minimized. Only then can a green IoT contribute significantly to a green environment and smart sustainability.

6 Conclusion

Key and important aspects are related to sustainability where the rapid development of IoT technologies must be carefully monitored from the point of view of resources and the environment to ensure balanced and sustainable development of IoT products.

The benefits of technologies that enable G-IoT are numerous, but their greatest contribution is reflected in the reduction of energy consumption and its savings, as well as the reduction of carbon dioxide emissions, which directly affects climate change and reduces global pollution. From an economic point of view, the application of green technologies reduces costs and creates the potential for improving the quality of life, the environment, economic growth and green global modernization.

Achieving a sustainable vision of the world through technological research and innovation can only be achieved by making the "right" choices in the early stages of their development. Traditional development can be significantly transformed into sustainable development by applying the G-IoT concept, using specially designed products and services for a sustainable environment. The focus of the implementation of the Green IoT for sustainable development can be fruitful only when global, national, regional and individual efforts are focused on cooperation and promotion of innovative design and implementation of IoT devices.

Competing Interest

The authors declare no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data Availability Statement

No data or additional materials were utilized for the research described in the article.

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