Towards Green IoT – A Sustainable Future

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The remarkable technological advancements in the field of Internet of Things (IoT) has tremendously impacted the way we work and live. It allows people, objects and devices to be connected anywhere, anytime for communication in a seamless manner. It offers a platform for sensors and devices to be connected seamlessly within a smart environment in order to provide effective, efficient and intelligent services. Although there are several advantages of IoT and its applications in our lives, but IoT also consumes energy, and adds to pollution with increased E-waste. This triggers the need for applications of IoT that utilize energy and other resources sustainably and in a manner that minimizes E-waste. Thus to increase the benefits and moderate the negative impacts of IoT, there is an increasing necessity to move towards green IoT. Green IoT is seen as an environment friendly application of IoT. Green IoT promotes measures to reduce the carbon footprint, conserve resources, and encourage adoption of techniques for efficient energy usage. Green IoT, being still in its infancy has several challenges in its actual implementation and imparting the proposed benefits for the environment and people.

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1. Introduction

Emerging New technologies have revolutionized our lives by providing anytime and anywhere access to information in ways that brings people, data and things, places, facilities together in unparalleled ways. The IoT refers to the rapidly growing network of connected objects such as home appliances, actuators, electronic gadgets that are able to collect and exchange data using in-built sensors. IoT technology integrates a variety of technologies such as sensor, automation, telecommunications, computer, RFID etc. Also, IoT is an innovation in the field of wireless communication where many intelligent agents are involved sharing information, making collaborative decisions and accomplishing tasks in an optimal manner [1]. IoT involves collection of data, using the data and communication among the associated devices. Thus Big data demands vast storage capacity, cloud computing, huge bandwidths and high power consumption for data processing. In order to deal with challenges such as increased energy usage, waste and greenhouse gas emissions, and to minimize the potentially negative influence of technological development there is the need for moving towards green IoT.

2. Green IoT

Green IoT is 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 the environment[2]. Green IoT is the application of IoT that sustainably uses
energy and other resources, in a manner that minimizes waste. Green networks in IoT will contribute to reducing emissions and pollution, exploiting environmental conservation and scrutiny with diminishing operational costs and power consumption. Green IoT has three precepts, namely, design technologies, leverage technologies and enabling technologies.

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Design technologies consider the energy efficiency of devices, communications protocols, network architectures, and interconnections. Leverage technologies refer to cutting carbon emissions and enhancing the energy efficiency. Due to green ICT technologies, green IoT becomes more efficient through reducing energy consumption, reducing hazardous emissions, reducing pollution and promoting optimal resource consumption. Consequently, Green IoT leads to preserving natural resources, minimizing the technology impact on the environment and human health and reducing the cost significantly. Therefore, green IoT is indeed focusing on green manufacturing, green utilization, green design, and green disposal [3].

3. Enabling Technologies for Green IoT

i. Green Radio Frequency Identification: RFID refers to small microchip which is used to store information of objects to which they are attached. Green RFID concentrate mainly on reducing the size of RFID tags which will help to decrease the quantity of non-biodegradable material used for manufacturing these tags as recycling them is difficult. For this researchers are designing energy efficient protocols and algorithms for collision avoidance, tag estimation etc.

ii. Green WSN (Wireless sensor networks) Base station and sensor nodes are the requisites of a WSN. Wireless sensor networks contain a large number of sensor nodes with limited power capability and storage capacity. A green WSN approach leads to working of sensor nodes only when they are needed. In order to reduce the consumption of energy, nodes are put in idle or sleep mode once the required activity has been carried out. Mechanisms that lead to reduction of data are also adopted by networking coding, adaptive sampling, aggregation and compression. Routing techniques that improve energy efficiency are also being adopted.
iii. Green Cloud Computing: Cloud computing offers high performance computing resources as well as high storage capacity to users. Users don’t need to manage or owe their own resources as they can share with ease access from pool of resources provided by cloud server. As more resources are being used and consumption of power is also more, so this leads to large extent emission of CO\textsubscript{2} and also other environmental hazards. Green Cloud Computing promotes the use of eco-friendly products which can be recycled and reused. Energy-efficient techniques need to be developed for resource allocation and optimal power usage.

iv. Green Machine to Machine: Machine to machine communication is done with help of intelligent nodes that gather data that has been monitored in M2M domain. A massive number of machines can communicate intelligently, share information and collaborate on decision making [15]. M2M is the advance version of IoT, where machines communicate with each other without human intervention. For this, methods have been adopted which increase efficiency of energy being consumed. Efficient protocols for communication are being designed. Several techniques that might be practiced to increase energy efficiency for greening IoT include intelligent power transmissions, efficient communication protocols, activity scheduling of nodes, energy-saving mechanisms and energy harvesting.

v. Green Data Center: Data center works in dissemination of various applications and data created by users. Huge amount of energy is consumed by these data centers, which leads to greater operational costs and high CO\textsubscript{2} footprints. Green Data centers can be implemented by utilization of dynamic power-management schemes, designing energy-efficient hardware techniques and architectures to consume power optimally.

vi. Green ICT Principles: Many principles are being incorporated to achieve green ICT such as turning off the facilities which are not needed from time to time. Sending only the data that is required, minimizing the length of path of data as well as wireless data. Power sources that are renewable such as fresh water, oxygen, solar energy and biomass are being used.

The Green Internet of Things (G-IoT) is predicted to significantly influence our lives and we can follow certain policies on keeping IoT communications technologies green.

![M2M Communication](image_url)
i. **Turn off service facilities that are not required.**

Energy consumption can be reduced if the facilities are turned on only when required and turned off when not in use. Sleep scheduling is one technique used for saving energy in wireless sensor networks, by making sensor nodes dynamically awake and asleep.

ii. **Transmit only relevant and required data.**

Large size data transmission consumes a lot of energy. Sending only the data essential for the users, can significantly reduce the energy consumption. Predictive data delivery is a technique based on user behavior analysis, used to provide only required data to users.

iii. **Minimal length of data path.**

1. Different routing schemes that consider the length of chosen path deem to be energy efficient.

iv. **Deployment of Advanced communication techniques.**

Green communications using advanced communication techniques like multiple-input multiple-output, cognitive-radio system can be used to improve efficiency. Renewable green power sources like oxygen, fresh water, solar energy are resources that are replenished naturally and reused. This will lead to reduction of emissions.

4. **Challenges for Green IoT**

Although there are ongoing efforts to popularize and adapt green IoT worldwide there are still a number of challenges that need to be focused upon:

- Increased energy efficiency and reduced complexity across the IoT architecture to achieve an acceptable performance.
- The devices and protocols used for communication should be energy efficient and consume less power.

- Deployment of green applications so as to minimize their effects on the environment.
- Increase in reliability of green IoT with development of optimal energy consumption models.
- Context-aware capability in IoT systems.
- Efficient cloud management in context of power consumption.
- Efficient security mechanisms should be implemented.

5. **Conclusions**

This paper discusses the various approaches towards design, implementation of green IoT and the principles involved in achieving a environment friendly IoT architecture. There are invaluable applications of IoT in different areas including medicinal, fabricating, mechanical, transportation, training, administration, mining, etc. Green IoT is an inspiration towards a green digital smart world.

**References**


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