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A Study on The Systematic Review of Green IOT

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Introduction

The rapid advancement in technology, especially the proliferation of the Internet of Things (IoT), has drastically transformed the way industries, businesses, and individuals interact with devices and the world around them. The IoT enables devices to communicate seamlessly with one another, enabling automation, remote control, and data analysis, leading to greater efficiency in various sectors. From smart homes and healthcare systems to smart cities and agriculture, the Internet of Things is quickly becoming an everyday aspect of life.

But as this vast IoT ecosystem increasingly proliferates, concerns regarding its environmental impact have started to grow. Considering the sheer scale of IoT devices and the enormous energy requirements of their communication and operation, energy consumption has increased manifold and electronic waste has also seen a marked rise. Furthermore, most conventional IoT systems consume huge amounts of power and resources, raising questions on long-term sustainability of such technologies. This approach comes in the form of Green IoT that is focused on designing energy-efficient and environmental-friendly IoT systems.

Green IoT integrates sustainable IoT technologies into conventional IoT systems to ensure that these systems meet sustainability standards without reducing their performance. Green IoT, by focusing on energy conservation, reducing carbon footprints, and responsible e-waste management, plays a critical role in reducing the adverse environmental effects of IoT deployment. This article attempts to conduct a systematic review of the concept of Green IoT, its significance, and its applications, bringing out the ways it contributes to sustainability and eco-friendly development.

What is Green IoT?

Green IoT refers to the combination of IoT technologies and environmentally friendly practices that enhance energy efficiency, reduce greenhouse gas emissions, minimize e-waste, and contribute to overall sustainability. Green IoT includes low-power devices, renewable energy sources, energy-efficient communication protocols, and innovative solutions such as edge computing and data processing optimization. With these sustainable practices, Green IoT allows smart systems to operate efficiently with minimal negative environmental impact.

Major Goals of Green IoT

The key goals of Green IoT are:

- IoT infrastructure shall reduce energy consumption.
- Use of renewable power sources, including solar and wind energy
- Longer lifespan for IoT devices so that they do not become obsolete in a short time and thus help reduce e-waste
- Using smart devices with minimum power consumption
- Reducing environmental impact through sustainable design and development

Key Principles of Green IoT

Energy Efficiency

The core of the Green IoT technology is energy efficiency. Energy consumption represents one of the biggest concerns over IoT systems because most IoT devices are continuously operating with high energy costs to transmit data and receive other data. But Green IoTs are designed towards reducing the overall energy consumption of an IoT network. This can be achieved through the use of low-power sensors and actuators, as well as the optimization of hardware components.

Energy-efficient IoT devices help reduce the consumption of both electricity and battery power, which is crucial in ensuring the sustainability of these systems in the long run. Low-power chips and energy-efficient batteries enable these devices to operate for longer durations without requiring frequent recharges or replacements.

Low-power Communication Protocols

The communication among IoT devices with their networks has a high rate of power consumption. Traditional communications protocols, which include Wi-Fi and cellular networks, require relatively high energy when transmitting data over significant distances. Instead, Green IoT uses low-energy communication protocols for minimal energy consumptions.

Energy-efficient communication technology examples include

- **LORAWAN (Long Range Wide Area Network):** Low power, long-range wireless protocol for connecting IoT devices over large areas with minimal energy use.
- **Bluetooth Low Energy (BLE):** A low-power wireless communication technology for short-range communication between devices.
- **Narrowband IoT (NB-IoT):** Cellular technology optimized for low-power wide-area networks.
- **Zigbee:** Low-power protocol for short-range communications, used in home automation and industrial IoT applications.

These protocols enable data to be transmitted effectively even in low connectivity or power resources.

Renewable Energy Integration

Green IoT incorporates the use of renewable energy sources such as solar, wind, and kinetic energy in powering IoT devices. In most rural or remote areas where traditional sources of power are not available, renewable energy-powered IoT devices are effective and sustainable solutions.

One example is the increasing popularity of solar-powered sensors in agriculture for soil moisture monitoring and crop health assessment coupled with environmental conditions. IoT devices, especially when placed with solar panels or small wind turbines, can operate independently, ensuring continuous monitoring without an external power supply.

This integration of renewable energy reduces the dependency on conventional power sources and helps in mitigating the environmental impact of fossil fuels.

Edge Computing for Data Processing

Edge computing refers to processing data closer to the location where it is generated, rather than sending it to distant cloud servers. In traditional IoT systems, data is transmitted to the cloud for processing, which not only increases energy consumption but also causes delays in decision-making. By processing data locally at the "edge," Green IoT systems can significantly reduce power usage and improve the overall efficiency of the network.

Edge computing enables IoT devices to make decisions quickly in real-time without needing to transfer large data back and forth to a cloud-based system. This reduces the load on the network and minimizes the energy required to transmit data, making IoT operations more sustainable.

Applications of Green IoT

Green IoT has many applications across industries that are helping to reduce environmental footprints and improving operational efficiency.

- **Smart Agriculture**

In agriculture, precision farming is implemented through resource-saving Green IoT solutions. To monitor soil condition and weather patterns to detect crop sickness and other relevant data, efficient energy sensors help the farmer understand irrigation, fertilizer application, and pesticides and thus decide. These resource-optimizing, Green IoT-based agriculture systems minimize water utilization and reduce inputs in the form of chemicals and prevent unnecessary exploitation of such resources.

For instance, the use of solar-powered irrigation systems allows for irrigating crops automatically following moisture levels detected in sensors, considerably minimizing water wastage. IoT solutions have also helped the farmer monitor any patterns of extreme weather conditions that may probably cause damage to the crops hence minimizing economic and

environmental loss.

- **Smart Cities**

It has also been on a significant rise concerning the development of smart cities in which it facilitates better energy management, waste management, and urban mobility. Cities can observe and optimize energy use through IoT-enabled devices such as smart meters, energy-efficient street lights, and waste bins, and this will ensure cost savings as well as environmental benefits.

For example, an intelligent lighting solution could have automated control, thereby it automatically can shift from day and no-motion settings depending on whether natural ambient is required. There are several benefits related to IoT in this system - reduces unnecessary movement; consequently reduces fuel used during a tour; cuts back on emissions produced from waste transfer trips Smart Healthcare

Green IoT is transforming the healthcare industry by offering efficient and remote health care. Wearable devices like a fitness tracker and a medical sensor will help patients know their health conditions in real-time but consume less energy. For instance, low power heart rate monitors and blood glucose sensors enable patients to monitor their health metrics without thinking about replacing their batteries too frequently.

Further, the remote patient monitoring system with IoT technology decreases the requirement for on-site hospital visits and subsequently decreases the carbon footprint created through transportation. It reduces health care costs while contributing to a cleaner environment.

- **Intelligent Transportation**

Green IoT is an important driving element for developing smart transportation systems. Smart transportation focuses on energy efficiency and reductions in emissions. For instance, IoT-embedded sensors within a vehicle monitor driving habits, monitor the fuel usage of vehicles, and track maintenance needs, significantly lessening energy consumption and reduction in the emission output of vehicles.

Furthermore, smart traffic management systems use IoT to optimize traffic flow, reduce congestion, and prevent unnecessary idling of vehicles. This reduces fuel consumption and the environmental impact of urban transportation.

Challenges of Green IoT

Despite its many advantages, Green IoT faces several challenges that must be addressed to unlock its full potential.

- **High Initial Costs**

High upfront investments may be needed in Green IoT system development and deployment due to sustainable technology, infrastructure, and research. High costs are involved initially while deploying energy-efficient devices and renewable energy solutions, though they help save in the long term in reducing operational costs and saving on energy consumption.

- **Interoperability Issues**

The integration of Green IoT systems into already existing infrastructure often raises issues of interoperability. Different producers' devices and systems may not be totally compatible with one another; hence, this might be a drawback in the smooth functioning of Green IoT solutions. Ensuring that devices from different manufacturers can exchange information and work in a coordinated manner without disruptions is a major challenge.

- **Security and Privacy Concerns**

With all IoT systems, security and privacy are the major concerns in Green IoT networks. The more devices connected, the greater chance of cyberattacks, data breaches, and violations of privacy. Therefore, secure communication protocols and robust data encryption are needed to protect user data and ensure the integrity of the system.

CONCLUSION

Conclusion By combining the benefits of IoT with the crucial requirement of environmental sustainability, Green IoT is a critical innovation that allows for energy-efficient devices, low-power communication protocols, renewable energy sources, and edge computing, thereby

enabling Green IoT systems to function efficiently while working toward less pollution. The applications of Green IoT in agriculture, smart cities, healthcare, and transportation all display its huge potential in the drive for sustainable development.

Though high initial costs, interoperability, and security-related issues are always present, it is undeniable that long-term benefits have been associated with Green IoT. Further advancement in technology and acceptance can help it reduce global energy consumption, reduce carbon emissions, and lead toward a more sustainable and eco-friendly future.

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