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RESEARCH ARTICLE

THE STATE OF THE ART IN ECO-FRIENDLY IOT

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ABSTRACT

Everything in the "**smart world**" is connected by the Internet of Things (IoT), making its energy consumption a challenging and alluring research topic. The goal of a green IoT is to create a network that uses very little energy. In this paper, we present an overview of green Internet of Things technologies. It also covers the four stages of the green IoT life cycle (design, production, use, and recycling) in detail. Also covered are green IoT technologies like green tags, green sensing networks, and green internet technologies. Research on the Internet of Things in 5G networks and for smart cities is also presented. Finally, some suggestions for further study and some of the remaining difficulties in the field of green IoT are offered. Green Internet of Things, 5G, wireless sensor networks, cloud computing, smart cities, and energy efficiency are some of the terms that can be found in an IoT index.

KEYWORDS

Internet of Things technologies, green sensing networks, green IoT

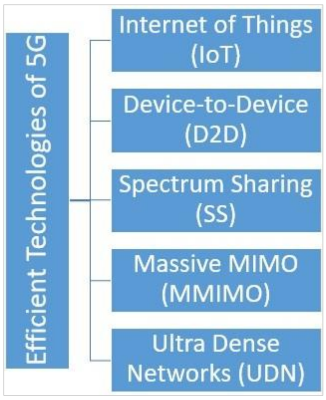
1. INTRODUCTION

Due to the proliferation of digital context, subscribers, and devices, energy consumption has skyrocketed over the past decade. By 2020, there will be as many as 50 billion connected devices (Elkhodr et al., 2013), and by 2030, that number could reach 100 billion (Accenture Strategy, 2015). Scientists predict a massive increase in data rate and content-size (ten thousand times greater in 2030 than in 2010) at the cost of exceptional carbon emissions (Green Power for Mobile, 2015). Carbon dioxide (CO_2) emissions from cellular networks are projected to reach 345 million metric tons by 2020 and are only expected to rise from there. In a study, we see a forecast of total emissions through 2020 (Fehske et al., 2011). In light of these massive (CO_2) emissions, environmental, and health concerns, renewable or green technology is emerging as a promising frontier in the technological revolution. Also, the current state of device batteries is a significant factor motivating the development of eco-friendly technology (IMT, 2015).

In the future, 5G wireless technology is expected to In 2020, we can expect fifth-generation communications, which, compared to current cellular systems, can handle mobile data roughly one thousand times faster (Albreem, 2015). Figure 1 depicts the five effective technologies used in a 5G network. Through a decrease in latency, communication between devices (D2D) improves user confidence in its reliability. Additionally, the UDNs involve dense small cell deployment in high-traffic areas. In addition, massive MIMO allows for a large number of antennas to work together to boost data transfer rates. Spectrum sharing's purpose is to prevent inefficient use of the available spectrum, while the Internet of Things' purpose is to rapidly connect multiple users across the globe.

As shown in Figure 1, 5G's Powerful Technologies time frame with maximum efficiency. These five cutting-edge methods should make it possible for the forthcoming 5G networks to use as little energy as possible, thus preventing any carbon dioxide (CO_2) emissions.

The primary goal of this paper is to offer a synopsis of green IoT in terms of core ideas, practical examples, relevant technologies, and significant obstacles. The fundamental ideas and requirements of the IoT are outlined in Section II. The entire eco-friendly Internet of Things (IoT) life cycle is described in Section III. The necessary technologies for green IoT are discussed in Section IV. IoT in 5G is the topic of Section V. The Internet of Things is introduced for smart cities in Section VI. In Section VII, we discuss the difficulties and potential future research avenues of green IoT. The final section, Section VIII, wraps up the entire paper.



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2. The IoT

Kevin Ashton, in a 1998 presentation, first coined the term "Internet of Things" and made the bold claim that "The Internet of Things has the potential to change the world, just as the Internet did." Possibly even more so (Ashton, 2009). The MIT Auto-ID centre first presented their Internet of Things vision in 2001. The International Telecommunications Union (ITU) adopted the term "Internet of Things" in 2005 (Brock, 2001; International Telecommunication Union, 2005).

One of the most endearing developments of the past decade has been the Internet of Things (IoT). It paves the way for seamless communication between devices, no matter where they may be or what network they may be using. It provides a mechanism by which sensors and other devices in a smart environment can be connected invisibly to deliver high-level and intelligible services.

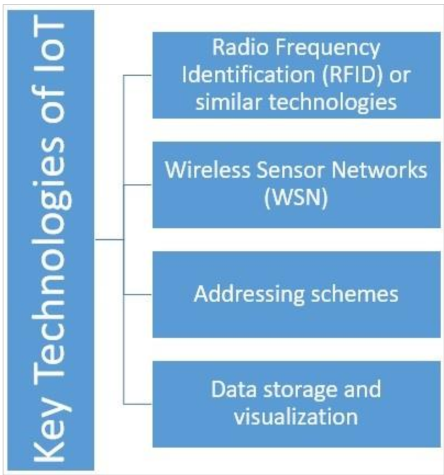

Figure 2.

Technology Backbone of the Internet of Things humane assistance from trained professionals. In Figure 2, we can see the essential technologies required for the Internet of Things, where sensors and devices sense and collect data of various types about the target, from which insights can be drawn to enable intelligent services. In a nutshell, IoT technology consists of four parts:

The Internet's role is to facilitate constant, global communication between any and all entities. Cloud computing, intelligent web services, and intellectual property for smart objects are all part of it.

Sensors, tags, actuators, and transceivers are all examples of hardware that constitute the embedded communication hardware.

Middleware: used for archiving data, processing it, and understanding its context.

The purpose of the presentation is to familiarize the audience with various visualization and interpretation tools across various environments and software.

Figure 3 depicts the many ways in which IoT can be put to use, including data management, analytics, visualization, heterogeneous network management, application development, and scientific inquiry. Figure 4 is an example of the beautiful infographic proposed by Libelium World that includes smart cities and IoT applications (Libelium, 2017). Those industries already adapting to the IoT have a firm grasp on its transformative potential and can see why it represents the next great technological leap. However, study of the IoT is still in its infancy, and there are many significant obstacles that must be overcome. These include issues with battery life (Meng and Jin, 2011; Keysight Technologies, 2015; Tozlu et al., 2012), the ease of use of the technology (Perera et al., 2014; Roselli et al., 2014), data and context awareness (Wu et al., 2014; Yan et al., 2017; Martin et al., 2010; Yan et al., 2017), and privacy and security (Ali et al., 2016). It is important to consider things like scalability (Perera et al., 2014; Wu et al., 2013), the cost of terminal devices, the number of concurrently operating objects, and the presence of a variety of endpoints (Zheng et al., 2012).

In order to recognize the behaviors, and even explain actions based on the information captured by the smart objects that are available around the emerging smarter cities, the Internet of Things (IoT) is an ecosystem which is not only a network to transfer data, but also interconnected with Big Data and Cloud Computing to provide intelligence (Palattella et al., 2016). Figure 5 depicts the IoT ecosystem architecture, which incorporates Cloud Computing to store and process data received from Smarter Cities. The presented flow facilitates cloud-human cooperation.

Figure 3.

Use Cases for the Internet of Things (FIG.3) who are becoming increasingly active participants (prosumers). Data from all sensors and devices is collected and stored centrally by the cloud computing system. Furthermore, it facilitates interaction and communication by establishing a pervasive network. It also addresses the issue of how to link together different systems. The cloud is also facilitating the incorporation of Big Data analysis, which is allowing researchers to better comprehend and identify patterns in human dynamics. At the end of the day, human dynamic pattern gives us the means and feedback mechanisms to motivate the alteration of behavior (Jara et al., 2014).

3. Ecologically Sound Internet of Things

The exponential future increase in network traffic and node count is baked into the concept of the "internet of things" (IoT). So, it's important to cut back on the energy needed to run the various nodes in the network and the materials used to put them in place. It is becoming increasingly important to minimize energy use in pursuit of sustainable, intelligent Internet of Things (IoT). international rollout The greenhouse effect and carbon dioxide (CO2) emissions of sensors, devices, applications, and services can be mitigated if the Internet of Things (IoT) is shown to be energy efficient.

The life cycle of green IoT is depicted in Figure 6; it involves designing, manufacturing, using, and disposing of devices in such a way that they have no or minimal negative effects on the environment (Murugesan, 2008).

4. Eco-Friendly IoT Technologies

Green RFID tags, a green sensing network, and a green cloud computing network are just some of the green technologies that could be incorporated into a green Internet of Things. In Figure 7, we can see the foundational technologies that will allow us to realize a sustainable Internet of Things.

The RFID system consists of a number of RFID tags and a similarly diminutive RFID reader. Information about the objects to which RFID tags are attached can be stored on the tags themselves. In most cases, RFID systems will only be able to transmit a few meters. RFID tags can either be "active" or "passive," depending on their level of interactivity. In contrast to the passive tags, the active ones are powered by batteries that allow them to constantly broadcast their signal. rather than

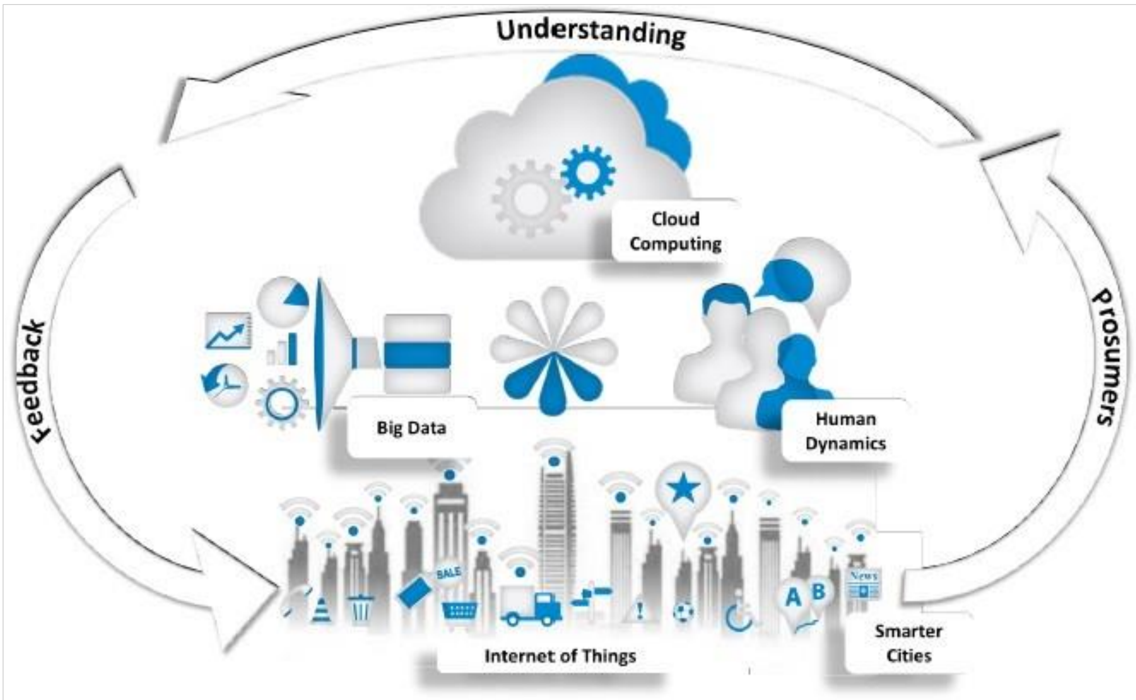

Figure 5: The Internet of Things Ecosystem (Jara et al., 2014).

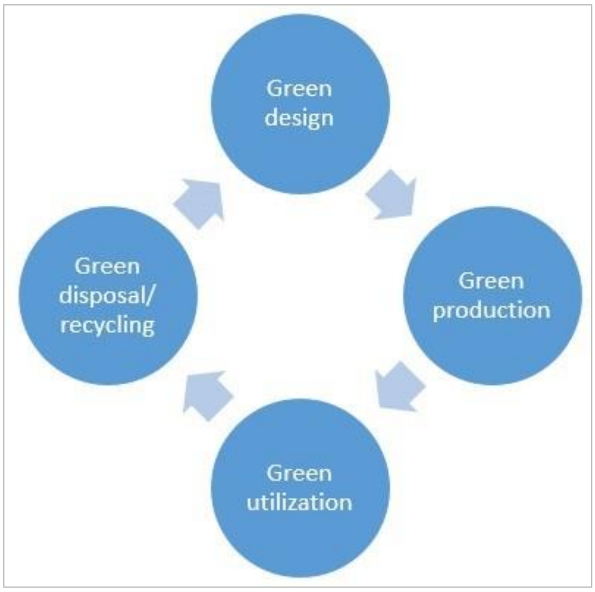

Figure 6: The Green Internet of Things' Life Cycle

The reader's signal to power their on-board battery, passive tags rely on syphoning power from the signal. Numerous studies have been conducted to get us closer to the green RFID goal. In light of the data presented in Table I, it is clear that

A table of contents

Timeline of green RFID study

An Overview of the Studies Conducted That Year:

IN 2008, RFID tags that decompose over time were proposed for use in the healthcare industry in 2008 (Mowry, 2008).

In 2010, three protocols were proposed to maximize energy savings at the reader by minimizing collisions between tag responses (Namboodiri and Gao, 2010). Automatic power stepping (APS), an RFID inventory algorithm based on tag response states and variable slot lengths, was proposed in 2011 (Xu et al., 2011). Reducing the power needs of active tags was the focus of two probabilistic estimation algorithms proposed in 2012 (Li et al., 2012).

In 2013, we proposed printing technologies for inexpensive RFID tags as a means of producing environmentally friendly tag antennas (Amin, 2013). In order to solve the overhearing issue in active RFID, the group proposed the Reservation Aloha for No Overhearing (RANO) protocol in 2014 (Lim et al., 2014). Reduce the bulk of RFID tags by using less nonbiodegradable material in their production, as suggested in 2017 (Shaikh et al., 2017).

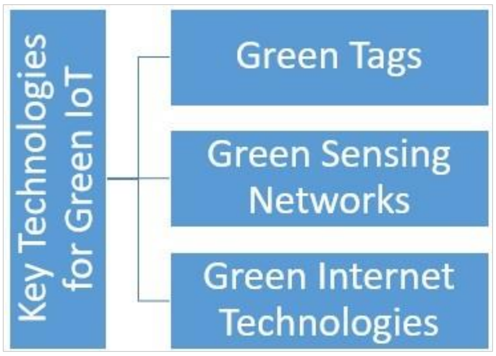

Figure 7: Crucial Green IoT Technologies

The proposed solution involves minimizing the amount of nonbiodegradable material by decreasing the size of RFID tags. Additionally, RFID tags that can be printed on are proposed. Additionally, various protocols are proposed to realize RFID tags that are low-power. Green wireless sensor networks (WSNs) are also an important component of the green internet of things. In a WSN, a large number of sensor nodes share limited resources like battery life and data storage. Many methods can be used to create a green WSN, including:

1. Once the sensor has completed its task, it will enter a low-power state, such as sleep, to conserve energy.

2. Please charge your devices and run your appliances on renewable energy. Vibrations and kinetic energy can also be put to good use.

3. It is important to employ optimization strategies that minimize energy consumption.

4. Cut down on data storage needs by employing data- and context-aware algorithms.

5. To lessen the burden on the vehicle's battery, eco-friendly routing strategies should be implemented.

6. Hardware and software must be taken into account for green internet technology, with hardware solutions producing devices that use less energy without sacrificing performance. Conversely, software solutions provide layouts that are both energy- and resource-efficient. Moreover, virtual machine techniques that reduce power consumption should be put into practice.

There are many uses and services for green IoT technology, as shown in Fig. 8. Includes "smart" infrastructure, "smart" energy and "smart grid" systems, "smart" manufacturing, "smart" healthcare, and "smart" logistics.

Figure 8: Green Internet of Things Applications

5. The Internet of Things for Fifth-Generation Wireless Networks

Fifth-generation (5G) wireless communications are expected to become widely available by 2020. 5G networks will be capable of handling mobile data at a rate one thousand times higher than current cellular networks. As a result, it will satisfy customers at reasonable prices, with high levels of dependability and impressive practicality (Ejaz et al., 2016). Connecting fixed and mobile devices, it will help usher in a new era of industrial and economic growth. The Internet of Things and fifth-generation wireless networks are two of the most exciting developments in tech right now. When put together, they have the potential to alter our future by making all systems interdependent (Rysavy, 2016). There are, however, many upcoming difficulties in designing IoT based systems that can be effectively integrated with 5G wireless communications (Palattella et al., 2016). Internet of Things (5G) security is a major issue. In addition, IoT features small data packets, massive connections of devices with limited power source, and delay tolerant communication. Coverage, power consumption, and terminal cost can all be enhanced in 5G through the use of narrow band system design. In order to accommodate the high number of low-rate, low-power devices expected in 5G networks, several IoT architectures have been proposed (Ijaz et al., 2016).

6. Smartcities and The Internet of Things

By 2020, the Smart City market could be worth hundreds of billions of dollars, with annual spending at nearly $16 billion (Zanella et al., 2014). It is based on a centralized design, with a large number of peripheral devices dispersed throughout an urban area, each of which generates its own unique set of data and can communicate with one another using any available protocol. This is why there is so much focus on sensing and automatic control, network infrastructure and communication, and big data analytics in IoT research (Ahlgren et al., 2016). There are many appealing Internet of Things (IoT) applications for the Smart City. Some examples include smart parking (Ramaswamy, 2016), environmental monitoring (Fang et al., 2014; Zhou et al., 2013; Montgomery, 2015), traffic management (Mahalank et al., 2016), waste management (Shyan et al., 2017), water management and quality, and energy consumption. In (Ganchey et al., 2014), a generic IoT architecture for smart cities and a categorization of IoT platforms are presented. The main difficulties encountered during the deployment and management of a city-scale IoT infrastructure in Santander, Spain, are discussed, and practical solutions are presented (Sores et al., 2017). This study presents the technical approaches taken to remove roadblocks in the Padova Smart City project in Italy. The connection between big data analysis and the Internet of Things is discussed in (Marjani et al., 2017). As well as this, a new framework for analyzing large amounts of data from the Internet of Things was proposed.

7. Problems and Future Research Goals

Despite extensive study, green Internet of Things (IoT) technology is just getting off the ground. There are numerous issues and problems that need to be resolved. We've outlined the primary obstacles below:

Acceptable performance in the IoT requires integration of energy efficiency across the architecture.

- Green applications are those that reduce their environmental impact.
- Energy consumption models for dependable green IoT.
- Awareness of current surroundings coupled with low power consumption via the Internet of Things.

Power consumption needs to be minimized across the board, from devices to protocols.

The simplification of the environmentally friendly Internet of Things.

There is a trade-off between dynamic spectrum sensing efficiency and spectrum management efficiency.

- Renewable and low-cost energy sources for IoT, like wind, solar, vibration, and thermal, that can power devices autonomously.
- Effective management of cloud resources with regard to energy usage.
- Command and control mechanisms and encryption that are both effective at their jobs.

8. Conclusion

Technology for a more environmentally friendly Internet of Things was covered in this paper. The paper's rationale for pursuing green IoT, along with its difficulties and rewards. The technologies necessary to realize a green Internet of Things (IoT) system were also discussed, along with the green IoT life cycle. Moreover, the contribution of IoT to 5G and smart cities is discussed. Additionally, opportunities and threats to future research are discussed.

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