Green IoT in terms of system approach

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Abstract - The Internet of Things (IoT) is a paradigm that aims to connect billions of devices to each other, anywhere and anytime. As IoT will be a ubiquitous technology, its sustainability and environmental impact are very important. Green IoT is considered the ecological future of IoT and plays an important role in which it contributes to improving the quality of life and providing a safe and healthy environment and ecosystem. A systems approach, based on the application of systems knowledge, appropriate methods and tools, provides the basis for observing green IoT through several different aspects by looking at the whole life cycle. This paper focuses on research into green technologies, green applications as well as green IoT infrastructure. It should be noted that this research does not cover the details of the IoT network and the perspective of connectivity, but focuses on the green aspect of the IoT network related to the creation of a hierarchical framework for green IoT. The proposed framework represents a unique view on the implementation of different approaches within green IoT systems, which are focused on the conservation of natural resources, in a way to minimize the impact of technology on human health and the environment.

Keywords - Systems approach, Green Internet of Things (G-IoT), Green technologies, Green Applications

I. INTRODUCTION

Every day, more and more devices are used for the so-called "smart solutions", so the question of environmental impact is a topic that needs more attention in research. In this context, the term "Green IoT" or GIoT (Green IoT) was coined, where numerous research activities are current, such as the use of renewable energy sources, reduction of energy consumption, an increase of energy efficiency, reduction of device size with reduced use of recyclable materials, etc. There are many reasons why it is smart solutions and G-IoT could be considered a key technological tool for smart, sustainable and inclusive growth of society. This paper will be based on an overview of different green technologies, green applications as well as green IoT infrastructure.

This research focuses on the green aspect of the IoT network related to the creation of a hierarchical framework for green IoT, which is monitored throughout the life cycle of both G-IoT and associated technologies and applications, as well as infrastructure reuse. Based on research related to green IoT systems [1], [2], [3] the lack of a comprehensive system framework has been noticed, which is necessary for quality design and selection of appropriate system architecture, technologies, principles, techniques, applications, etc. Different systems approach, systems analysis, and the consequently established system architecture will bring together different aspects of the implementation of green IoT systems.

First of all, it is necessary to analyze trends, previous research, and give an overview of different visions for future development. It will then identify key issues and challenges for future research.

Achieving one of the goals of green IoT, which refers to the reduction of waste and pollution, and the use of non-renewable materials implies the importance of recycling and reuse of materials and devices[4]. The life cycle of green IoT is focused on green disposal, green production, green design, and ultimately green recycling so that the environmental impact is negligible[5].

The usage of green technologies and green IoT is reflected in increasing environmental benefits and reducing environmental pollution, making them important factors contributing to the development of a green economy. The plan to introduce a billion "smart" devices in the coming decades will contribute to a significant process of economic transformation, new jobs and economic development, but also cost savings and sustainable growth of society[6].

II. MOTIVATION

Most of the research so far is based on the analysis of individual technologies, as well as applications that are realized using these technologies.

The motivation for researching the issue of green IoT based on observation of the entire life cycle came from the idea that it is possible to create a framework that will unite the providers of green IoT and create the possibility of extending the life cycle. Extending the life cycle is reflected in the main goals of green technology, and they relate to the reuse of devices, their recycling, reducing energy consumption, the use of renewable energy sources, as well as reducing waste.

III. GREEN IOT: DEFINITIONS AND ENABLERS

Different definitions and visions behind the G-IoT paradigm can be found in the reference literature. Most approaches to observing, understanding, and defining G-IoT are based on increased energy efficiency and reduced carbon emissions[7].

Green IoT focuses on reducing energy use for IoT, as a necessity to fulfill the idea of a smart world and the sustainability of the intelligence of everything, as well as reducing CO2 emissions[8]. Green IoT in [9] defines as a

study and practice of designing, using, manufacturing, and disposing of various computer and network systems efficiently and effectively with minimal or no impact on the environment.

Green IoT is based on three concepts. The first relates to design technologies and to the energy efficiency of devices, communication protocols, network architecture and interconnection. Another concept is impact technologies related to reducing carbon emissions and increasing energy efficiency. Thanks to green ICT technologies, green IoT becomes more efficient through the reduction of energy, hazardous emissions, resource consumption and pollution. Accordingly, green IoT leads to the conservation of natural resources, thus reducing the impact of technology on the environment and human health and significantly reducing costs The observation of green IoT focuses on green production, green use, green design, and green disposal [10], as presented in Figure 1. The goal is to realize the design and production of equipment with minimal impact on the environment, saving energy consumption, and increasing the reuse of electronic equipment and their recycling.
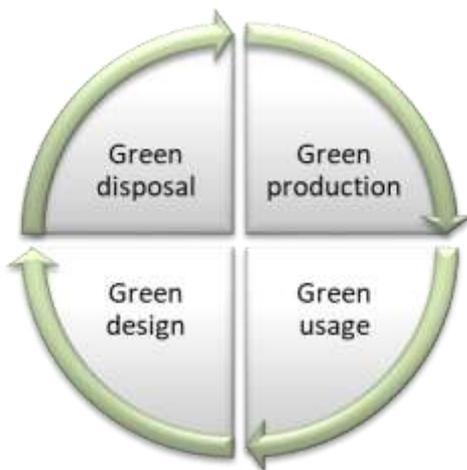

Figure 1. The life cycle of G-IoT observation

In the continuation of the paper, we will present the components of G-IoT by the proposed system approach.

A. *Green technologies that enable G-IoT*

The development of technology in the field of IoT has changed the way of life and enriched society with its advantages, but we must not ignore the fact that IoT consumes energy, contributes to toxic pollution, and generates electrical waste. Green technologies mean the development of energy-efficient technologies including computer and communication technologies. These technologies imply lower energy consumption through more efficient use of available infrastructure. Green IoT technologies are evolving in different parts of the IoT system architecture. This part of the paper will present a comprehensive overview of green IoT technologies and strategies that demonstrate efforts to build a green and sustainable world, making the environment safe and healthy, and contributing to a smart and high quality of life based on enabling technologies, reducing pollution and energy consumption [4].

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 2.

In recent years, we have witnessed the widespread acceptance of RFID technology in many important application domains. RFID tags are used as automated devices to collect data and enable the connection of objects via networks. RFID plays an important role in striving to make the world greener by saving energy consumption, reducing vehicle emissions and improving waste disposal. During the last years, there has been increasing research [5] on green RFID [2] [8] related to reducing the size of RFID tags due to recycling, the use of a minimum amount of non-degradable material in production, as well as the use of protocols for maximum energy savings in readers.

The idea of green IoT in wireless sensor networks is to keep the sensor in sleep mode for most of its life to save energy. Many new techniques enable green IoT sensor networks such as sensor selection, sensory recognition energy costs, and energy-saving sensor sleep schedules by reducing communication between sensor nodes[11]. With changes in sensor operation, power consumption is minimal and battery life is extended. One of the ideas of a green WSN to enable green IoT is presented in [5], which focuses on extending network life, increasing energy efficiency, reducing system budgets, and reducing relay nodes.
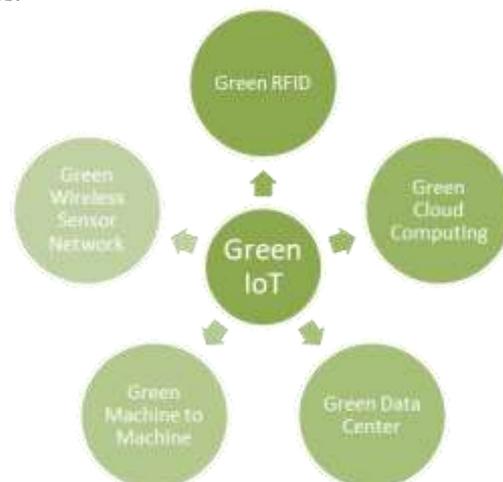

Figure 2. Green IoT Technologies

Cloud computing and green computing are the two most popular areas of information and communication technologies with numerous applications worldwide. Combining cloud computing and IoT has a wide range of research. The primary goal of green cloud computing is to promote the use of environmentally friendly products, and the primary purpose of the GCC is to reduce the use of hazardous materials, maximize energy savings, and increase the recyclability of old products and waste. This ultimately leads to paperless virtualization, product

longevity, efficient resource allocation [10]. On the topic of Green CC, several papers have been performed that provide some of the solutions related to energy-saving by using different techniques for allocating resources for energy efficiency, but also efficient energy saving techniques.

Device-to-device (M2M) communications are a core part of IoT. M2M is considered an advanced version of IoT, in which devices communicate with each other without human intervention. For the better realization of green M2M, various techniques of reducing energy consumption are proposed [12]. The World Organization for Standardization (GDS) supports the idea of implications for energy efficiency through various standardization activities related to M2M communications.

Green Data Centers (GDCs) are data storage and management facilities that consume huge amounts of energy[13]. To improve energy efficiency for GDCs, it is necessary to use green energy sources, dynamically manage energy, and build efficient power supply models.

The idea of green communication and networking refers to low CO2 emissions, low radiation exposure, and energy efficiency. Due to these facts, Green Communication plays a very important role in Green IoT.

The green internet has become a topic that many researchers are actively dealing with. Internet technologies are used to develop smart and green networks. The idea of greening the internet aims to reduce electricity consumption with increased efficiency. The concept of Green Technologies will help preserve the environment and improve it to ensure the survival of civilization. Green technologies and environmental sustainability are focused on the goals of green technologies related to the development of new energy-efficient and environmentally friendly systems.

B. Green IoT Applications

Potential IoT applications are numerous and diverse, covering virtually all areas of everyday life.

The green application implies the application of IoT solutions to improve the quality of the environment in terms of reducing pollution. An example of such solutions is cost-effective IoT systems for monitoring air and water pollution, which enable obtaining results on the impact of individual pollutants, which allows appropriate activities to be taken. Such systems have multiple benefits because they enable adequate and timely decisions to be made to improve air and water quality as well as to identify key causes (sources) of pollution. Several other examples greatly affect the environment, such as IoT systems for waste management, systems for optimizing traffic routes that cause harmful emissions from vehicles, systems for detecting possible fires, etc.

Green IoT applications are aimed at saving energy and the risk of pollution, reducing the greenhouse effect, as well as the impact of IoT itself on the environment. Key trends in green IoT in the domain of applications related to smart grids, smart homes, industrial automation, healthcare, and smart cities[14]. Each of these applications covers specific areas of application of green IoT.

Smart cities aim to reduce CO2 emissions through smarter traffic management, waste management, environmental monitoring, and the creation of a safe environment. This is achieved through specific areas of G-IoT application that include smart roads, parking management, smart waste, smart buildings, and smart environment.

Healthcare refers to the collection of real-time patient data. Great efforts are currently being made to provide energy-efficient solutions by building green hospitals and green equipment that requires very low or no energy sources.

IoT has enabled the development of a smart industry using a large number of sensors and software, which contributes to reducing the use of energy and resources and greenhouse gas emissions. The characteristics of green technology are related to waste reduction, efficient use of materials, use of alternative raw materials, and hiring competent human staff.

New green technologies, such as green-IoT, can increase productivity and growth by converting factories into high-performance facilities, efficiently managing resources and reducing waste and pollution, saving energy, and extending the overall life of the system[15].

Smart houses refer to the application of G-IoT to increase convenience and reduce costs, which is achieved through enabling control of lighting in the house, control of heating, as well as control of electronic devices in the house using a smartphone or computer. Smart energy management introduces advanced and smart technologies into the energy management process, which is one of the goals of G-IoT.

Smart grids find their field of application in industrial automation, solar energy, and energy independence. The smart grid can dynamically adjust and readjust for energy delivery at a low cost while still guaranteeing high quality.

C. Green infrastructure

Green infrastructure implies the development of IoT components in an environmentally friendly way with the possibility of renewal and reuse of old electronic equipment and their recycling to reduce waste. How to make various IoT components such as network devices, computer equipment that includes computers and smartphones, power batteries, etc. environmentally friendly and ready for reuse after the end of their life cycle. This means more efficient use of recyclable materials after certain components or systems stop being used or when they need to be replaced with newer ones. Particular emphasis must be placed on the challenge of extending battery life as well as recycling these components. In practice, there are numerous other challenges related to the treatment of electronic equipment and its reuse in the implementation of green IoT systems.

IV. PROPOSAL OF A FRAMEWORK FOR THE IMPLEMENTATION OF G-IoT USING A SYSTEMS APPROACH

Based on the above facts, it can be concluded that the impact of IoT on the environment must be observed at all layers of the system architecture and from different aspects and approaches. All components of the system must be considered, as well as the efficiency of their joint work, which indicates the need to develop a systemic framework for green IoT. This framework would include the principles of the development of green IoT systems and the selection of the best technologies, applications, and infrastructure for their development and application (figure 3).

Figure 3. Proposal of a framework for Green IoT

The purpose of the proposed framework is to observe the entire life cycle of the green IoT paradigm. Green IoT technologies demonstrate the work and efforts to build a green and smart world, which contributes to a safe and healthy environment, a smart and high quality of life.

Green IoT applications are numerous and diverse, and cover virtually all areas of everyday life. They are aimed at reducing CO2 emissions, saving energy, and the risk of pollution. Not only does green IoT help other industries reduce the greenhouse effects, but it also reduces the environmental impact of IoT itself.
Green infrastructure means the development of IoT components in an environmentally friendly way with the possibility of renewal and reuse of old electronic equipment and their recycling to reduce waste and extend the life cycle of IoT components.

V. CONCLUSION

Lots of fascinating and useful solutions enabled technological development in the age in which we live. In recent years, G-IoT has attracted the attention of the research community, as trends in G-IoT technologies prove that life has become easier for us, cities smarter, and the world a better place to live. To create a systemic framework, proposed in the paper, in addition to a good knowledge of the systems approach, it was very important to interact with other approaches such as product lifecycle management. By combining several different approaches guided by a systems approach, best practices are combined and integrated into development processes to ensure interdisciplinary, structured, and connected development of the appropriate system. Specifically, in creating the framework for green IoT, we wanted to present and impose a systemic way of thinking whose application can lead to the creation of a sustainable and ecological world through more efficient use of resources, reduction of energy needs, pollution and waste generation. Raising people's awareness of the importance of thinking about how to make existing technologies and applications environmentally friendly, and extend the life of devices as part of green infrastructure, was an important step in creating a systemic framework for our research. Considering the green IoT as an open dynamic system, it can be represented by an input-output matrix, where input connections to the system would be different requirements or conditions related to the choice of more environmentally friendly technologies and its applications, while outputs refer to those connections that they represent the system's response to the environment, which are the reduction of CO_2 emissions, energy savings, energy efficiency of devices (things) in the G-IoT network and other connections with the environment that make IoT greener. This paper provides an effective insight into all segments of green IoT without going into the details of the IoT network and the connection perspective. We believe that the industry's interest in the field of green IoT makes its future brighter, and the full involvement of the research community will realize the vision of green IoT.

REFERENCES

[1] S. J. Akshay Gapchup, Ankit Wani, Ashish Wadghule, "Emerging Trends of Green IoT for Smart World," www.ijircce.com, vol. Vol. 5, no. 2.

[2] S. H. Alsamhi, O. Ma, M. S. Ansari, and Q. Meng, "Greening Internet of Things for Smart Everythings with A Green-Environment Life: A Survey and Future Prospects," pp. 1–14, 2018.

[3] S. H. Alsamhi, O. Ma, M. S. Ansari, and Q. Meng, "Greening internet of things for greener and smarter cities: a survey and future prospects," Telecommun. Syst., vol. 72, no. 4, pp. 609–632, 2019.

[4] V. Balasubramanian, N. Kouvelas, K. Chandra, R. V. Prasad, A. G. Voyiatzis, and W. Liu, "A unified architecture for integrating energy harvesting IoT devices with the Mobile Edge Cloud," IEEE World Forum Internet Things, WF-IoT 2018 - Proc., vol. 2018-Janua, pp. 13–18, 2018.

[5] A. Marra, P. Antonelli, and C. Pozzi, "Emerging green-tech specializations and clusters – A network analysis on technological innovation at the metropolitan level," Renew. Sustain. Energy Rev., vol. 67, pp. 1037–1046, 2017.

[6] A. Castillo and A. D. Thierer, "Projecting the Growth and Economic Impact of the Internet of Things," SSRN Electron. J., 2015.

[7] J. Shuja et al., "Greening emerging IT technologies: techniques and practices," J. Internet Serv. Appl., vol. 8, no. 1, 2017.

[8] G. Li, D. Z. B, K. Xie, T. Huang, and Y. Li, "Energy Efficient Sleep Scheduling for Wireless Sensor Networks," vol. 1, pp. 688–701, 2015.

[9] S. Murugesan, "Harnessing green IT: Principles and practices," IT Prof., vol. 10, no. 1, pp. 24–33, 2008.

[10] S. K. Routray and K. P. Sharmila, "Green initiatives in IoT," Proc. 3rd IEEE Int. Conf. Adv. Electr. Electron. Information, Commun. Bio-Informatics, AEEICB 2017, pp. 454–457, 2017.

[11] F. K. et al. Shaikh, "Enabling technologies for Green Internet of Things," IEEE Syst. J. 11, vol. 92, no. 2, pp. 983–994, 2017.

[12] M. Zhou, Q. Cui, R. Jäntti, and X. Tao, "Energy-efficient relay selection and power allocation for two-way relay channel with analog network coding," IEEE Commun. Lett., vol. 16, no. 6, pp. 816–819, 2012.

[13] F. K. Shaikh, S. Zeadally, S. Member, and E. Exposito, "Enabling Technologies for Green Internet of Things," IEEE Syst. J., pp. 1–12, 2015.

[14] M. Maksimovic, Internet of Things and Big Data Analytics Toward Next-Generation Intelligence, vol. 30. 2018.

[15] C. Zhu, V. C. M. Leung, L. Shu, and E. C. H. Ngai, "Green Internet of Things for Smart World," IEEE Access, vol. 3, no. January, pp. 2151–2162, 2015.