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Green IOT: A Primer

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Abstract The Internet of things (IoT) allows people and things to be connected anywhere, anytime, with anyone and anything. These connected items consume substantial amount of energy. Green IoT aims to reduce the energy consumption of IoT. It plays a significant role in achieving a sustainable smart world. This paper provides an introduction to green IoT.

Keywords IoT, green IoT

Introduction

The Internet technology has provided many beneficial applications for our daily lives. It has played a major role in the flourishing every sector of the economy. Recently, we have witnessed more and more devices interconnected through the Internet, creating Internet of Things (IoT). IoT bridges the gap between the cyber and physical world, enabling billions of connected devices to communicate. It may be regarded as the advance version of machine-to-machine (M2M) communication, where every object connects with another object without human intervention.

The aim of Internet of Things (IoT) is to connect devices or things (e.g., car, sensor devices, mobile phones, cloud computing systems, people, RFID network, GPS network, 5G network) from the physical world to cyber world and let them interact with each other. These things are consuming substantial amount of energy. Thus, the greenness of IoT is critically important for the success of IoT. Green IoT focuses on reducing the energy consumption of IoT, thereby fulfilling the smart world with sustainability

Internet of Things

Internet of Things (IoT) is a newly emerging concept, which aims to connect billions of devices with each other. The Internet of Things (IoT) comprise of a number of technologies and research disciplines that enable global connectivity over the worldwide physical objects. IoT is the next step in the evolution of the Internet since it takes into consideration all devices connected to it. It allows all types of elements (sensors, actuators, personal electronic devices, laptops, tablets, digital cameras, smart phones, alarm systems, home appliances, or industrial machines, etc.) to autonomously interact with each other. It allows things to be connected, sensed, and collaboratively communicate over the Internet. Integration of every device with the Internet necessitates that devices use an IP address as a unique identifier. To some extent, the future of IoT will be limited without the support of IPv6.

There are four main technologies that enable IoT [1]: (1) Radio-frequency identification (RFID) and near-field communication, (2) Optical tags and quick response codes, (3) Bluetooth low energy (BLE), (4) Wireless sensor network. Applications of IoT include smart grid, smart cities, smart manufacturing, education, e-health, food supply chains, and intelligent transportation. Although the benefits of IoT are great, IoT consumes energy and embraces toxic pollution and e-waste. The rechargeable batteries for IoT devices has limited life span and this

makes IoT technology to be on the verge of inadequate battery power. Green IoT is regarded as the future of IoT that is environmentally friendly [2].

Enabling Green IOT

The exchange of large amount of information among billions of devices connected to IoT creates a massive energy need. Green IoT promises to achieve a lower power consumption than IoT and make the environment safer. The life cycle of green IoT contains green design, green manufacturing, green utilization, and green disposal with a minimal impact on the environment, as shown in Figure 1 [3]. Monitoring the waste is crucial for proper recycling.

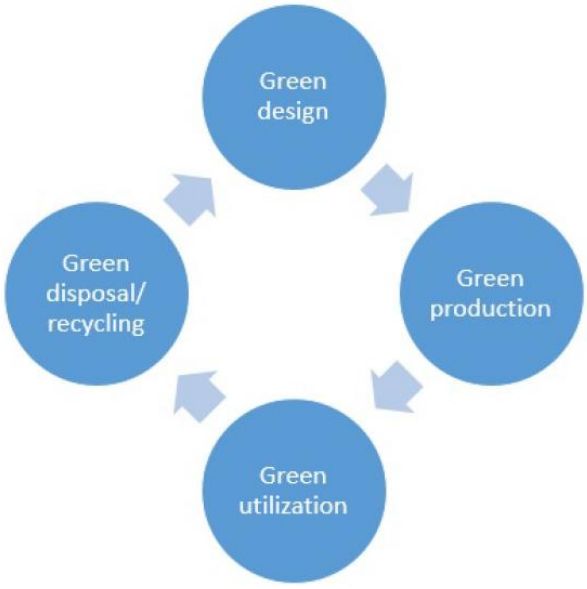

Figure 1: Life cycle of green IoT [3]

The five technologies enabling green IoT are [4]: green RFID, green WSN, green CC, green DC, and green M2M.

Green RFID: The RFID (radio-frequency identification) is a small electronic device that includes several RFID tags and a small tag readers. The tags are used in storing information regarding the objects to which they are attached. Green RFID may mean reducing the size of RFID tags.

Green WSN: WSN (wireless sensor network) consists of sensor nodes which are equipped with sensors that take readings (e.g., temperature, humidity, CO_2 detector, soil control etc.) from the surroundings. Green WSN may imply making sensor nodes only work when necessary and using data and context-awareness algorithms to reduce the data size.

Green CC: (CC) (cloud computing) offers three kinds of services for different applications: IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service) and delivers computing as a utility. With applications being moved to cloud, more power is consumed causing CO_2 emissions. The green cloud computing concept has an important role in reducing energy consumption in IT industries. Green cloud computing is becoming important due to the increasing concerns about environmental issues by cloud service providers. Data management and efficient infrastructure are critical to facilitate green cloud computing.

Green DC: DC (data centers) consumes a lot of energy with high operational costs and large CO_2 footprints. To improve energy efficiency of DC may require using renewable energy or green sources of energy (such as wind, water, solar energy, heat pumps).

Green M2M: M2M (machine-to-machine) is a technology that allows both wireless and wired devices to communicate with other devices of the same type. It allows machines to consume the information other

machines generate. It involves massive machines and consumes a lot of energy. Green M2M may involve switching some nodes to low-power operation/sleeping mode.

With the advances of these enabling technologies, green IoT has a great potential to enhance economic and environmental sustainability. To achieve green IoT, the following principles should be considered [3]:

- Turn off devices that are not needed.
- Use renewable energy for charging and utilization purposes.
- Use energy-efficient optimization techniques.
- Use data and context-awareness algorithms to reduce the data size.
- Use energy-efficient routing techniques to reduce the mobility power consumption.
- Send only data that are needed.
- Minimize length of wireless data path.

Applications

IoT and green IoT have a wide range of applications and services. These include smart grid, smart city, smart home, smart healthcare, remote monitoring, agriculture, and industrial automation [5]. Some of these are illustrated in Figure 2 [6]. The green Internet of things (G-IoT) is predicted to introduce significant changes in our future daily life and lead to a green environment.

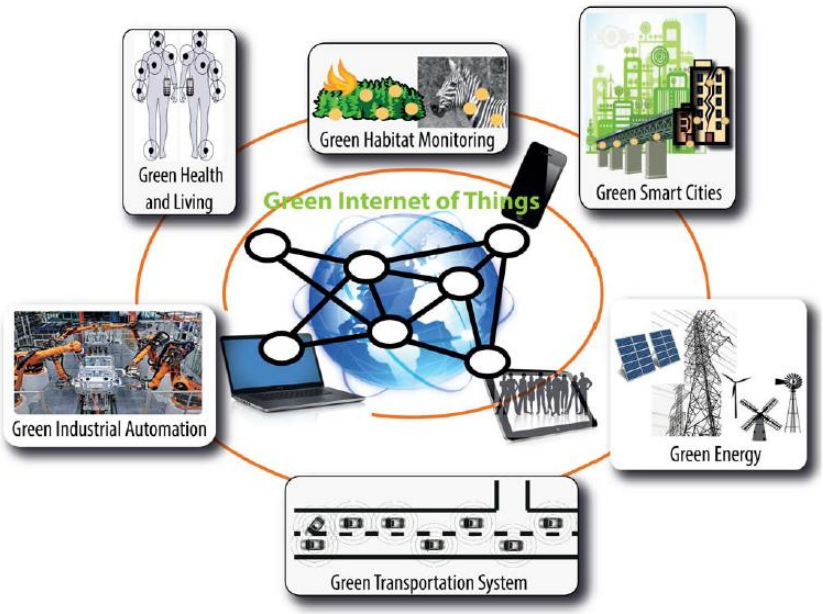

Figure 2: Green IoT applications [6]

Challenges

Green IoT faces a lot of challenges that need to be addressed before the full realization.

Reliability is a major challenge for achieving green IoT, because not all sensor nodes are expected to simultaneously be active in IoT domain. Achieving green IoT through the use of 5G poses new challenges due to the need for transferring huge volume of data in an efficient way. Cybersecurity remains an outstanding challenge of green IoT.

Conclusion

The Internet of things (IoT) will interconnect every aspect of people's world in the smart world. It will control critical infrastructure such as the smart power grid, smart cities, smart manufacturing, and smart transportation systems. As IoT becomes a pervasive technology, its sustainability and environmental effects are critically important. Green IoT is IoT technology tasked with enabling a greener society. It is regarded as the future of IoT

that is environmentally friendly. Green IoT is still in its infancy and its adoption faces many technical challenges.

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