A Survey on Energy Management Evolution and Techniques for Green IoT Environment

I. Shanmugapriya

Abstract The introduction of Internet of Things (IoT) has benefitted smart cities, healthcare, and transportation applications for enabling smart connections and analyzing the performance. As the number of IoT devices and potential connectivity increases, the distance between smart hubs, smartphone software complexity, and people behaviors changes rapidly resulting in a power utilization challenge. Energy efficiency and power dissipation are two of the most significant challenges in green IoT-enabled technologies. Based on a systematic literature review, this study presents the power management possibilities in the Internet of Things (IoT) domain. The main purpose of this study is to develop energy-efficient approaches for WSNs that enable IoT. The "Green IoT" concept aims to reduce the energy consumption of IoT devices while maintaining sustainability conditions. In this study, which is driven by establishing a viable IoT environment for the future phase and moving the globe toward the formation of Green IoT, a review of Green IoT (GIoT) is first provided, and then the challenges and potential possibilities for GIoT are studied.

Keywords Cloud computing · Green Internet of Things (IoT) · Machine-to-machine (M2M) · Near-field communication (NFC) · Radio-frequency identification (RFID) · Wireless sensor networks (WSNs)

1 Introduction

Internet of Things (IoT) is gaining an increasing research interest among Information and Communication Technology (ICT) researchers. The term Internet of Things (IoT) is described as a network of billions of things/people connected to one another [1]. The communication between IoT devices can be established at any point of time and any place by employing different services via any link. IoT is a heterogeneous environment, which includes a number of nodes, such as sensors, RFID tags, RFID readers, and mobile devices [2]. Internet of Things (IoT) is more than simply

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a network for transferring data; it is a system that uses big data processing, events, and protocols. The advancement of IoT technology provides opportunities but also challenges. Many problems exist in the IoT research subjects including data analysis and storing, transportation, digital transfer, safety, communications, and power administration, which remain as the different aspects of information analysis and storing [3].

For a daily routine, IoT technologies are playing a significant role in human lives. It is also known that IoT will emerge as a revolutionary technology, capable of transforming the world into a digital space [4, 5]. Internet of Things (IoT) has the potential to connect thousands of digital objects. It is frequently considered as an advanced version of machine-to-machine (M2M) communication, where each machine or digital entity interacts with each other without any human involvement [6]. IoT and similar innovations cover a wide range of devices, including actuators, sensors, access points, and portable gadgets, which remain connected to the web and capable of detecting their surroundings, transferring data, and establishing communication in different ways [7]. IoT devices utilize energy to function and run, just like any other device. However, in a few cases, these devices consume much more energy than is required, resulting in energy wastage through the formation of unwanted heat. This wastage of energy and unnecessary temperature must be reduced to benefit the economy and ensure environmental safety. The quantity of energy required to operate a gadget has increased due to the recent technological developments and the continuous growth of functional IoT devices. This has paved way for the growth of GIoT or low-power IoT [8]. According to reports, the Internet of Things (IoT) will be instrumental in preventing future natural calamities by adopting low-energy consumption practices [9].

The increasing number of energy-consuming digital devices and wide variety of digital domains, the energy consumption rates have increased unprecedently [10]. The utilization of connected IoT gadgets is growing at an exponential rate, as well as the amount of data produced and moved throughout the IoT model has prompted the researcher to predict the high data rate and large content size, which leads to an unavoidable carbon cost [9]. According to recent research reports, the increased amount of carbon dioxide generated by mobile systems are predicted to reach 345 million tons by 2020 [11]. Pure or green technology are developing as an important study area due to the increasing large carbon dioxide outputs as well as the ecological and medical issues. However, there are a number of issues with the GIoT ecosystem as a whole, including the issues with security and service quality, as well as the complexity of using a global framework, heterogeneous devices, etc. As a result, researchers are working to create new alternatives such as unique GIoT solutions and the incorporation of supportive technologies such as cloud computing, fog computing, and other similar technologies to address these issues. The primary goal of this research work is to make the readers have a short outline on GIoT and usage of GIoT methods to develop an eco-friendly sustainable world.

2 Green Internet of Things

This section provides a taxonomy to emphasize the technical aspects of energy management and green computing technologies in any IoT environment. Figure 1 shows a novel taxonomy for enabling energy management in Internet of Things (IoT) systems. Six categories can be used to categorize the study on energy management and power consumption solutions in I/O settings: Smart technologies include, smart grids, smart energy collection, smart cities, smart industries, and smart building and environments.

With the IoT experiencing several challenges like security and privacy, and interoperability [12], the most important challenge faced during the implementation of IoT is energy consumption. The power consumption will increase as there are more Internet-connected IoT devices including RFIDs, sensors, actuators, and mobile devices [13]. A high amount of energy is required on a daily basis if billions of IoT devices are operating continuously, and also a huge amount of data will be produced. Additionally, the energy required to transfer and store the large-scale data increases exponentially. As a result of this excessive energy consumption, an increasing amount of carbon dioxide (CO_2) will be discharged into the atmosphere without any limitations. GIoT is presented as a solution to these challenges [14].

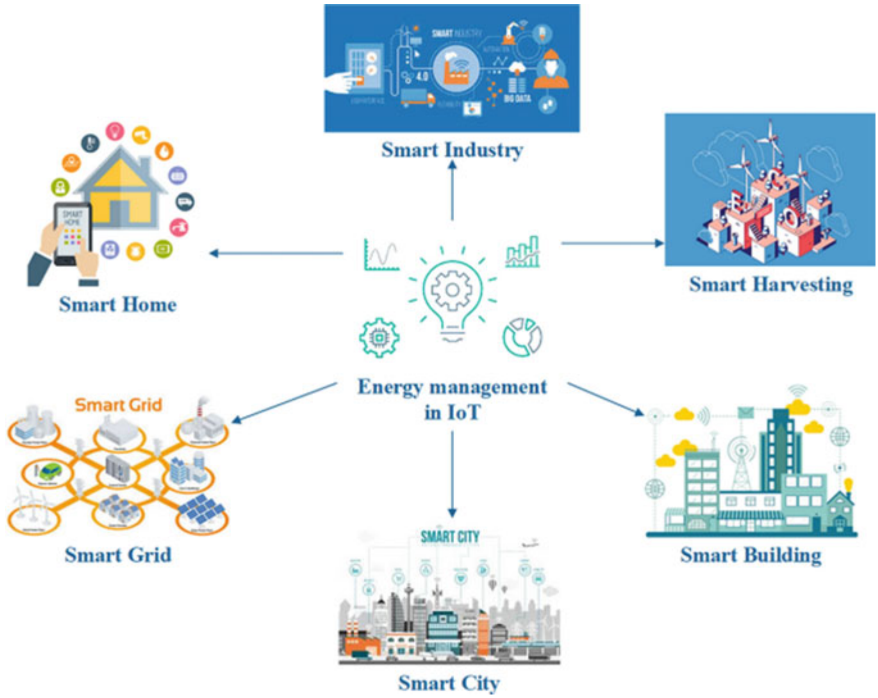

Fig. 1 Proposed taxonomy for energy management solutions in IoT environments

3 Literature Survey

This section provides a comprehensive literature review of all the recent concepts for energy-efficient IoT deployment. Due to the rapid depletion of traditional energy resources and the exponentially increase in energy consumption, green IoT has gained potential research interest in the ICT industry.

Miorandi et al. [15] explained about various methods and technologies helpful in attaining energy efficiency in the IoT, however there was no discussion on system models that are precisely developed for Green IoT. Baliga et al. [16] compared the energy usage of cloud computing and PC computing in various circumstances and it was concluded that selecting the models based on scenarios would be the best option. Additionally, these estimates do not include Quality of Service (QoS) issues, which may enhance energy consumption in certain instances. Green technologies for the implementation of IoT by considering the QoS across different domains were studied in [17]. It is directly aimed at generating solutions for Green IoT. The background of an IoT network, the information center and cloud computing, as well as its green solutions, were not highlighted.

Akkaya et al. [18] described various mechanisms for saving energy in smart buildings. This is accomplished by using the data gathered through IoT, and it was discovered from the respective systems that in case of heating, when proper ventilation and air conditioning systems are in place, huge amounts of energy can be saved. Despite all of the existing research works, the comparison of energy preservation concepts has not been examined.

Wireless sensor networks (WSN) is considered as an important element in the implementation of IoT. Shaikh and Zeadally [19] discussed about the taxonomy of the methods employed for harvesting energy in WSN by applying various environmental resources in detail. However, instead of batteries, another media for energy storage could result in high energy effectiveness; therefore, this field requires extensive research.

An energy evaluation approach for smart homes based on the MQTT communications protocol in an IoT environment and Big Data was developed and tested by Al-Ali [20]. The proposed energy management system makes use of analytics, and business intelligence. The proposed approach uses benchmarking to perform data mining and also uses a business intelligence platform to instantly produce graphs, charts, and reports. Further, the suggested solution enables users to operate and monitor the equipment remotely, create online invoices by using a user-friendly mobile application, and provide novel techniques for enabling smart energy management based on IoT and Big Data. The proposed method highly emphasizes on speed and security parameters to enable efficient energy management systems in wireless sensor networks (WSN). A number of parameters were developed to assess the system performance, including storage, database speed measurement, and scalability in MQTT servers.

Cho et al. [21] proposed an IoT-based technique for limiting the energy consumption in household appliances. The proposed algorithm is divided into three modules:

first is the heterogeneous network end device module, which is a framework that translates the processing of various devices into recognized standards for other devices, as well as the administration systems; second is the electric appliance-oriented interoperability module, which includes a sub-module; third is the electric appliance-oriented interoperability module, which is considered as the most important module in the proposed algorithm. The technology is then tested on home appliances present in a smart house for a particular period of time. This method can be implemented with the use of local and worldwide Internet connection techniques such as Bluetooth, ZigBee, and others. Finally, the power precision and recollection metrics were assessed. The potential challenge observed here is smart management, which is defined as the precise identification of the efficiency and energy distribution of all devices at the same time period. Upcoming research must concentrate on predicting the user behaviors and employing a recognition model with hybrid data like image and position.

Li et al. [22] have reviewed the procedures for designing an IoT-based Self Learning Home Management System (SHMS) based on machine learning. Features like power alert, price clustering, and price estimate, for which machine learning technology has been extremely useful in the implementation and development, are among the recommended strategies. In the suggested method, a smart home was used to simulate the system design. A smart plugin has been considered to track the amount of power used, and data analysis was also used to optimize power dissipation based on the product utilization. The authors provided a suitable method for monitoring the amount of electricity consumed, after which the smart home model will get optimized by reducing the additional demand for power supply and the cost associated with its utilization.

An Internet of Things (IoT) based smart home management system was created by Naik and Patel [23]. JSON is the algorithm used in their proposed model. The filtering will only be applied in this technique once when the data is submitted to the server, and later the retrieved information will get stored. For connecting and managing microprocessors, sensors, and Internet-enabled devices via web servers, smartphone apps or databases are utilized. Xenserver and a microcontroller board are used in this project. After completing the development of proposed system, the authors have experimented it for several months. The outcomes of their work are compared to other contemporary technologies in terms of price and performance metrics, such as reliability and energy consumption to know about the effectiveness of the proposed technology. The proposed technique has the advantage of being able to check the regional climate and dynamically modify the room temperature; nevertheless, the system security has not been ensured in this research.

In the domain of home power administration, Park et al. [24] have explored numerous varieties of predicted risks and elements that impact the risk factor of IoT. The demographic variables have also been explored. There have been discoveries of security, privacy, financial, electromagnetic radiation (EMR), and other risks. The observed EMR is the most effective value. The writers have specifically considered the individual's choice, which includes sensitivity to changes in electricity consumption, ecological degradation, and so on. Also, two vital factors include the changes in electricity cost and adoption of novel technology. Possibly, the users concern about EMR even though the researchers have perceived cyber security threats as the drawback of ICT services. However, the exploration on the relevance of demographic variables along with perception of risk has gained more research attention and it is important to carry out extended research works.

Kamienski et al. [25] introduced a system, where the system operation is carried out through traceable graphical contexts to manage data based on the scalable IoT systems in smart cities. The developed representations form the elementary principles are far behind the illustration of the technique used in this system. An application has been introduced to realize the context principles and designs. This article attempts to provide an environment in which these user-designed contexts require tracking, and this system should also ensure data security. The approach has been further examined from various perspectives, including error detection, modification, and platform effectiveness. This approach has a restricted scope of the context awareness framework, and it requires new techniques to improve it.

Designing a deep reinforcement learning (DRL)-based IoT fog node design focused on power efficiency applications has been developed by Liu et al. [26]. This research work provides information on enabling energy administration in smart cities. Edge computation is used to introduce the software foundation of an IoT-based environment. Since the IoT system is employed in smart cities, the smart environment faces numerous challenges in detecting and conducting strong control actions in compliance. As a result, the evolving DRL is a potential technology comprised of the deep neural networks (DNN).

Sodhro et al. [27] proposed two algorithms, HABPA and DSA to achieve the goal of developing green and robust smart communities. The smart city applications have been extended to several sectors of society, including health care, industry, and media streaming. IOT connects the devices connect with one another, but a substantial amount of energy is consumed by them, therefore the algorithms (HABPA and DSA) are implemented to establish a balance between energy resources and system requirements by maintaining the efficiency of the smart city and prevention of data loss. Attempts have been made to make the best use of recyclable green energy sources rather than the simulated ones. It can be inferred from the results that both the algorithms are very efficient though there are few challenges to be addressed, they are: buffer area and the amount of increase in energy consumption. It is expected that developed technologies will be expanded into health care system in the near future.

Terroso-Saenz et al. [28] have presented the IoT Energy Platform (IoTEP) to find a solution for the energy operational issues, which include a large amount of energy consumption and wastage. It is found that the existing techniques are insufficient to solve the current problems, for example, the sensing system used in apartments do not have the ability to deal with the energy loss. Hence, IoTEP technique is proposed to optimize the ways in which the energy is balanced in buildings by using data probing, energy savings can estimate the energy requirements. IoTEP will not only reduce the energy loss but also yield the advantages of personated energy criticism for incorporating more enhancements. In the near future, other approaches can be synchronized with the proposed technique. It is also expected that these hybrid forms would yield improved results in this field.

Pawar and Tarun Kumar [29] presented an IoT-based intelligent energy administration platform with no constraints or limits for the utilization of renewable energy resources. The suggested method was designed and constructed to represent the assessment of different architectures.

Tom et al. [30] introduced an IoT-based technique for measuring and regulating the energy depreciation with the goal of increasing the use of eco-friendly and green energy. Since IoT-enabled homes and devices are connected to the internet, the data consumption levels, occupants' demands, high-consumption devices, peak hours, and the expenses incurred by each model may be collected. As a result of these assessments, the power utilization framework for smart homes is found to be likely to result in predicting the estimated power consumption, peak periods, and participatory requirements for the next three days, and the results are communicated to customers via demand response (DR) scheme. The main purpose of this research work is to balance the energy usage during peak hours while decreasing the consumption and resultant cost. If the residence permits it, the utility may be authorized to regulate and use the auto-control equipment.

Salman et al. have proposed a novel energy management system for smart homes. This technology was designed specifically for sensors and cameras as it was determined to be unsuitable for the heterogeneous nature of IoT environment. Furthermore, it does not have the ability to adapt to the systems capable of transmitting large amounts of data, such as IoT environment [31].

Ku et al. have developed a smart energy service for Internet of Things (IoT) applications. The collection of energy data is required for this service. The major drawback in this service is that it does not address the problem of fault tolerance, as well as the lack of trials that involve IoT infrastructure [32].

Choi et al. [33] have developed a power monitoring system for a particular type of public environment, this technique is characterized as a special purpose system. Furthermore, the research studies are not exclusively designed to provide reliable outcomes that satisfy the emerging research requirements.

Prathik et al. [34] developed a system for scaling the energy consumed by IoT technology (i.e., the IoT technology is utilized in the form of a tool in this technical work). There is no solution proposed in this research for dealing with the energy utilization challenges in IoT.

In order to adopt IoT-based energy approaches with smart plugs, Srinivasan et al. [35] have developed a smart strategy, but it was not energy critical at the same levels of IoT energy-based nodes. Also, the implementation part has not considered the unique characteristics of Internet of Things (IoT).

Kumar et al. [36] proposed an IoT-based energy harvesting system. This system has not considered the issue of IoT power utilization, especially for non-renewable energy nodes.

Chaouch et al. [37] considered a machine-to-machine statement to develop an energy management approach with an intent to monitor and reduce the energy dissipation. Due to its architecture, this system is considered as a special purpose system.

Panahi et al. [38] investigated a smart mechanism that can be used to charge the mobile sensors wirelessly by using the IoT technologies. This intelligent method's modeled testing ground is inadequate to show the IoT environment because it focuses solely on the WSN ecosystem, ignoring RFID and other energy-based nodes.

Only a real-time surveillance method for energy levels identified in the IoT systems is suggested by Alaudin et al. [39].

A hardware design that can change the rate of energy consumption was studied by Tcarenko et al. [40].

Suresh et al. [41] proposed a theoretical technique to reduce the sensor node energy dissipation in the IoT environment.

Using IoT technologies, Yaghmaee et al. [42] have developed a smart power measuring device by including a cloud server, smart plugs, and a gateway. When combined with a defect in the IoT standards, the results of this system has become incorrect and inadequate.

In the IoT environment, Pan et al. [43] suggested an energy surveillance mechanism and lower power usage rates. This system is also built by considering a specific goal. Furthermore, its deployment testing strategy does not reflect the characteristics of IoT.

Ding and Wu [44] proposed a schedule method for minimizing the energy loss. Because this model was evaluated in a WSN rather than an IoT situation, the findings could then be utilized in IoT.

Ejaz et al. [45] have involved in developing an optimal and planned energy-efficient model for smart cities, as well as the energy collection to extend the life of low-power products. The efficacy evaluation of this system is poor due to its dependency on four devices. It has failed to consider the enormous amount of data that could be exchanged in a smart city or over the Internet of Things.

4 Inference from Existing Work

GIoT can enhance people's lives and the environment by strengthening the eco-friendliness of the technologies and the associated infrastructure. Recently, GIoT research is focused on developing energy-efficient models and scheduling, energy-efficient RFIDs, green IoT systems and solutions, and GIoT device localization [46]. Furthermore, the majority of IoT devices are expected to be designed to be recyclable as many times as possible, thereby lowering the number of toxic and dangerous materials discharged into the environment. Furthermore, it is expected that the GIoT systems would progressively combine the supportive technologies such as cloud computing [47], fog computing, edge computing, and blockchain, since these techniques may improve the basic IoT environment's sustainability, security, and efficiency [48–50].

5 Conclusion

This paper explores the sustainable strategy of IoT. The most recent efforts in the green IoT domain as well as the potential sectors requiring attention in the future for green IoT are reviewed. There is a collection of IoT technologies that can positively impact the environment and conserve energy. This study investigates the key enablers of green IoT, and examines how they make the best use of diverse techniques to improve energy efficiency. To offer a sensitive connection across diverse domains of green IoT, including heterogeneous combinations, sensor cloud integration, proper service administration, and adverse physical environments, the standardized frameworks are necessary. Several global initiatives have been proposed to promote and accommodate the green environment. Further, the recent research initiatives and standardization efforts are reviewed, and their future perspectives are also highlighted. From the proposed review, It is envisioned that the increased industrial focus on green IoT will boost its future prospects, and that researchers and industrialists will be fully involved in implementing the goal of green IoT.

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