# A Short Survey on Energy Efficiency, Harvesting, and Management for Internet of Things

**S. S. Karthik[1], Dr. V. Vijayalakshmi[2], Dr. G. Zayaraz[3]**
[1]SAP / ECE, Christ College of Engineering & Technology, Puducherry, India.
[2]Associate Professor / ECE, Puducherry Technological University, Puducherry, India.
[3]Professor / CSE, Puducherry Technological University, Puducherry, India.

**Article Info**

***Article history:***

Received Sep 21, 2024
Revised Oct 13, 2024
Accepted Nov 26, 2024

***Keywords:***

Energy Harvesting
Energy Management
Internet of Things
Wireless Sensor Network

**ABSTRACT**

Internet of Things (IoT) is a promising technological advancement comprising tiny sensors, intelligent computing devices, cloud, storage, humans, etc. This fundamental architecture and infrastructure of IoT are constructed using sensors and self-powered devices. Energy efficiency and management are a vital part of this platform for sustainable services and application support. This review article discusses notable energy efficiency, harvesting, and management techniques in IoT. This article aims to provide a short study on the notable methods based on classification. The classification techniques are discussed with the novel methodologies and the summary of classes are provided.

***Corresponding Author:***

S. S. Karthik,
SAP / ECE, Christ College of Engineering & Technology,
Puducherry, India.
Email: karthsivashanthi@gmail.com

## 1. INTRODUCTION

The design of Internet of Things (IoT) with low-power embedded computing and communication systems have improved the operating time of devices. Conserving power and battery capacity optimization are used to accomplish the long operating time [1]. The sensing, movement, and interaction capabilities of mobile devices in the Internet of Things paradigm rely on an independent power supply [2]. Future real-time applications will face significant challenges with power consumption and distribution due to the heterogeneous components housed inside the Internet of Things (IoT) model. This necessitates integrating economical and effective energy harvesting and power-saving methods with the Internet of Things platform [3,4]. In order to provide power-based solutions for identifying services along with application sharing, environmentally friendly methods of routing have been established. The protocols assist energy conservation, harvesting, and distribution without increasing the complexity. Nevertheless, real-time Internet of Things applications are less compatible with the protocol's support for heterogeneity [4,5].

Energy management solutions are demanding with the increase in urbanization and IoT services. The technology-based applications and the life quality improvements do not reverse the energy demand coupled with the IoT platform [5,6]. Real-time applications can be precisely predicted, planned, and commissioned with IoT-based energy management technologies [3,5]. To balance the demand and function of the smart environments, smart grids, buildings, residences, etc., depend on aided management of energy, which includes energy collection and the deployment of different sources. The IoT platform offers context-aware smart options for energy management, harvesting, distribution, and conservation [7, 8]. Four strategies for conserving energy in IoT settings are briefly reviewed in the section that follows.

## 2. WIRELESS SENSOR NETWORK BASED IOT

Wireless Sensor Network (WSN) forms the fundamental element of the IoT environment for data sensing and aggregation. The design and energy management methods for IoT are planned based on WSN nodes. Based on this fact, the different organizations of WSN in IoT are discussed below.

For IoT-oriented software-defined wireless sensor networks (WSNs), Ding et al. [7] proposed an energy-conserving relay selection method. This method is designed using adaptive and reactive routing algorithm support. Based on the Markov chain, software-defined wireless sensor networks (SDWSNs) are investigated to calculate state transition probability (STP). The best relay is found by performing DRA-EERS. Dijkstra shortest path algorithm outperforms well to improve the energy efficiency and to adjust the link weight coefficient.

Cloud-backboned IoT paradigm requires intense energy saving utility, that is designed in [8] using an adaptive neural learning in WSNs. The network performance is improved by the proposed method by minimizing the energy overhead trade-off. A decision-making system qualifies the nodes. The performance of cloud-assisted IoT is improved, assessed using the metrics network lifetime and response rate. Contrarily, the delay, request failure, and overhead of the network are comparatively less.

For providing lifetime endurance of wireless ad-hoc IoT networks, Yan et al. [9] suggested an energy optimized topology management algorithm in 5G and B5G.A Static based algorithm evaluates the network topology. Robust backbone topology is built by a maximum spanning tree algorithm. The Energy-Efficient Topology Control algorithm (EETC) is used to increase the network lifetime.

Shah et al. [10] implemented interoperability dependent energy conscious routing in clustered IoT-WSNs for throughput optimization. The network throughput is increased by conserving energy during the routing process. The proposed framework is used to decrease the device-device delaysand to maximize the data transfer rate. The desired result is obtained by customized, localized behavior, and proactive routing strategies.

## 3. ENERGY EFFICIENCY APPROACHES IN IOT

For communication, information exchange, and resource access, IoT systems depend on wireless devices. For IoT platforms to appear more resilient and long-lasting, energy efficiency is therefore essential.

The role of fog computing architectures in optimizing energy is reliable. Naranjo et al. [11] introduced such architecture for resource handling and delivering for the real-time assistance for IoT applications. This architecture is distributed through virtualizationVirtual processors' dynamic scaling to increase or decrease processing rate and the Transmission Control Protocol/ virtual connections' transport throughput are used to jointly minimize the suggested heuristic. The suggested methodology outperformed the current resource handling methods.

Hybrid data collection and the energy-saving mechanism were used by Ibrahim et al. [12] in sensing-based IoT applications. The data exchange between the cluster heads (CH) is reduced through data compression, gathering, and forecast techniques. Data collection is reduced by active/ passive interactions and malleable frequency. Data clustering techniques remove the redundancy in collected data. To assess the energy-conserving mechanism's performance, its efficiency is contrasted with the current approaches.

Kaur et al. [13] designed a big data-supportive associated framework in IoT setups for energy-competent Software-defined Data Centres (SDCs). The sub-optimal method is presented using the first fit decreasing algorithm. The network's energy utilization is saved by the proposed framework when compared to the existing scheme. A multi-objective optimization problem deduces optimal allocation of resources.

Ammad et al. [14] introduced a fog-aided energy-conserving framework for IoT applications. This framework operates in multi-level for meeting the energy requirements and distribution of smart applications. The framework uses the sensor-modeled hardware layer and the policy layer to achieve energy efficiency. The suggested paradigm is validated by a case study in smart agriculture, smart parking systems, smart hospitals, and airports. The simulation tool iFogsim toolkit was used for simulation purpose.

Energy-conscious offloading using mobile edge computing for IoT was designed by Li et al. [15]. The energy drain due to heterogeneous device support and connectivity is handled by this offloading technique. Better energy efficiency among various end devices is satisfied by the proposed method. The iterative solution framework addresses power allocation, distribution issues in data exchange through offloading. The authors have analyzed the resource sharing and offloading features of the proposed method.

Kumar et al. [16] suggested energy-focused improvements in WSN-IoT environment for green communication. Sensor devices energy is conserved using dedicated optimization model. The performance of the proposed method is compared with the modern technique. The advantages of the suggested approach are illustrated by evaluating energy-competing measures. Table 1 provides a short highlight on technology, application support, and other methods under the WSN class.

Table 1. Features of the WSN Detection Approaches

| **Feature** | **[11]** | **[12]** | **[13]** | **[14]** | **[15]** | **[16]** |
|---|---|---|---|---|---|---|
| Integrating Technology | Fog | - | Data Centres | Fog | Edge | - |
| Application Support | High | High | High | High | Low | Low |
| Data Aggregation Support | ✗ | ✓ | ✓ | ✗ | ✗ | ✗ |
| Latency | High | Low | Low | Low | High | Low |
| Network Lifetime | Medium | High | High | Medium | Medium | High |

## 4. ENERGY HARVESTING IN IOT

Energy Harvesting (EH) is a convincing method for enduring the battery power of IoT devices. Depending on the purpose and needs of the gadget, this is accomplished using renewable, green, and alternative energy sources.

A routing algorithm that supports energy saving in heterogeneous IoT networks is designed by Nguyen et al. [17]. This algorithm operates in a distributed manner for different devices in the IoT platform for unanimous allocations. With the proposed algorithm with various energy harvesting techniques, the node's lifetime is improved, and the quality of services of the network is also improved. The performance metrics are investigated for various energy harvesting conditions. The proposed framework improved the energy efficiency and was compared with existing routing protocols.

Energy harvesting cognitive radio networking is recommended by Ozer et al. [18] for IoT-enabled smart grids. An energy harvesting technique is suggested for IoT wireless devices in order to address resource constraints. The network paradigm is described by the operation of energy collecting analytical radios, unit design, and network architecture. Issues and directions for future research are analyzed for enabling the proposed method.

A joint optimization for data transmission and energy handling is considered by Ashraf et al. [19]. In this method energy harvesting and distribution for IoT sensors is achieved. The communication is reliable and guaranteed by an intelligently controlled energy queue. Low queuing delays are ensured by organizing the first-in-first-out data storages. The proposed method is assessed using simulations and the results using delay, energy, and data rate are analyzed.

Tang et al. [20] created decentralized compute dumping for an Internet of Things fog-based system's extraction of energy. Performance and Quality of Experience (QoE) are optimized in the suggested work. The optimal solution is found by the Lagrangian approach and policy gradient method. The effectiveness of this scheme is assessed using a comparative study with the methods from the literature.

Classification of energy-saving techniques is considered in [21] for IoT-based heterogeneous wireless nodes. Common taxonomy is proposed, and major energy conservation techniques are covered for reviewing and categorizing papers. To introduce the classification perspective and to show the divisions of each category, each category is briefly discussed. Table 2 provides some feature comparisons of the methods discussed in [17], [19], and [20].

Table 2. Comparative Analysis of the Features

| **Feature** | **[17]** | **[19]** | **[20]** |
|---|---|---|---|
| Energy Conservation | ✓ | ✓ | ✓ |
| Data Rate Improvements | ✓ | ✗ | ✗ |
| CPU Utility | Low | Low | High |
| Data Queue Utilization | Low | High | Low |
| Residual Energy Consideration | ✓ | ✗ | ✗ |

## 5. ENERGY MANAGEMENT IN IOT

As an integrated component of IoT operations, the total energy administration carries out energy harvesting, transportation, and conservation. The conventional or dedicated infrastructures are cumulatively utilized for this purpose.

Yu et al. [22] proposed a novel architecture using IoT environment for building energy handling and intelligent residences. The Web of items (WoO), which is housed in this architecture, consists of various items and devices that provide a web-based Internet of Things applications and services. Mashup is provided to networks by service composition, and service federation is introduced. The new architecture uses metadata, profiles, and resources to choose the best object for the smart energy prediction approach.

Zhong et al. [23] suggested ADMM based distributed auction mechanism in smart buildings for energy hug scheduling. With the help of optimization of energy, scheduling will allocate the energy to hug managers. Distributed implementation of the auction is implemented to mitigate the computational burden.

Simulation is done to evaluate energy scheduling performance and verify the auction mechanism's incentive compatibility.

In [24], a fog-based architecture is used for transitive energy administration systems. Being a part of Internet of Energy system, the proposed architecture supports HTTP, Open ADR, and COAP. Different communication network metrics and various grids considered for studying the performance of the proposed architecture. Fog and cloud assimilated models delay performance and bandwidth is calculated by the proposed method.

Said et al. [25] suggested an energy management plan for a green IoT ecosystem. The volume of the data transmitted is minimized; the work is scheduled for IoT nodes' critical energy. The inevitable energy problem is addressed to provide fault tolerance. EMS and NS2 network simulator construct intensive simulation. The proposed method outperforms well than the existing techniques.

Tom et al. [26] considered smart energy handling and requirement satisfaction for IoT- fog-based power sharing systems by consumers and utilities. From the historical data, the customers' behaviour is studied, and energy demand is predicted. During peak hours, the significant role of each appliance is found. The use of electricity consumed is noted, and the demand is reduced during peak hours.

Design and development of advanced smart energy management systems integrated with IoT framework are implemented by Pawar [27] in a smart grid environment. A smart energy management system replaces the complete power outage. The maximum demand limit is considered for various scenarios, and the order of priority is changed. Reliable ZigBee communication is developed for data analytics and storage. A descriptive comparative study of the above methods under energy management is presented in Table 3.

Table 3. Descriptive Comparison of the Methods in Energy Management

| **Feature** | **[22]** | **[23]** | **[24]** | **[26]** | **[27]** |
|---|---|---|---|---|---|
| Power Requirement Prediction | High | Medium | Medium | High | High |
| Cost Effectiveness | × | ✓ | ✓ | × | × |
| Mean Square Error | Low | High | Low | Low | High |

## 6. CONCLUSION

This article presents a short survey on different energy optimization methods for IoT. The methods are classified as WSN-based, energy efficiency, harvesting, and management. The fundamental role of WSNs in energy optimization and overall energy management in IoT has been classified and discussed in the article. The common features identified from each classification are presented as a comparative analysis for providing a quick insight into the highlights. The methods discussed in this article are limited, though; the most recent approaches/ methods are discussed for their precise achievements and impacts over IoT.

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