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Energy Efficient Protocols for Wireless Sensor Network : An Overview

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ABSTRACT

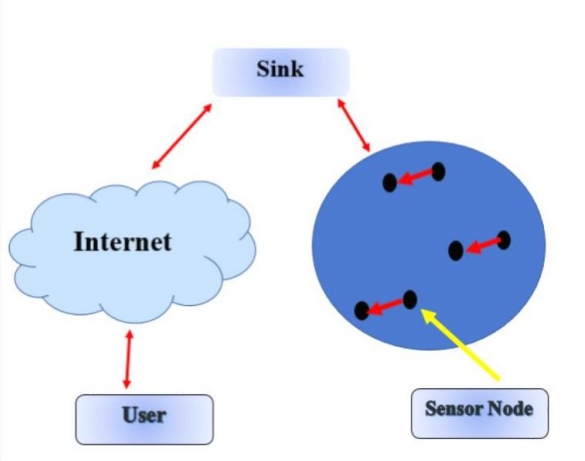
As IoT is accepted across the world and the nodes connected are increasing rapidly through various applications like Smart Homes, Smart Cities, Health Care, and many more. The physical objects have a limited number of resources on which they rely like energy, bandwidth, and memory. The working of physical objects is affected due to these limited resources. Energy Efficient Protocol (EEP) is one solution to it, which is important in increasing the life of a physical object and smooth working of it over the network. This paper gives an overview of EEP that are being used and implemented in WSN.

Keywords: Energy-Efficient Protocol (EEP), Wireless Sensor Network (WSN), Internet of Things (IoT)

I. INTRODUCTION

Energy-efficient cluster head selection is crucial for Wireless Sensor Networks (WSNs) in the Internet of Things (IoT) to prolong the network's lifetime and enhance its overall efficiency, since sensor nodes typically operate on limited power sources, such as batteries. Physical objects in WSN have less number of resources available while working to transmit the collected data over the network. Conservation of energy can be done by implementing an EEP, to maximize their life it is important. These protocols are designed such that they work on less energy to be consumed while performing the task like transmitting the collected data across the WSN. These protocols must be reliable in saving energy. Energy-efficient protocols research has made significant progress, but there are still some notable gaps and challenges. This paper provides information about the lacunae in research, the types of EEP, their significance, and their characteristics.

Different EEP in WSN: In the WSN model (Fig. 1), In WSN the EEP is used to transmit the data over the network, where the user is having control over the sensor nodes via the internet, connected through a main node called Sink, which acts as a root node.



EEP is classified into three types mainly based on functioning mode, participating style, and network structure as shown in Fig 2. Clustering, Data-Centric, and Medium Access Control are their subtypes, they are described below

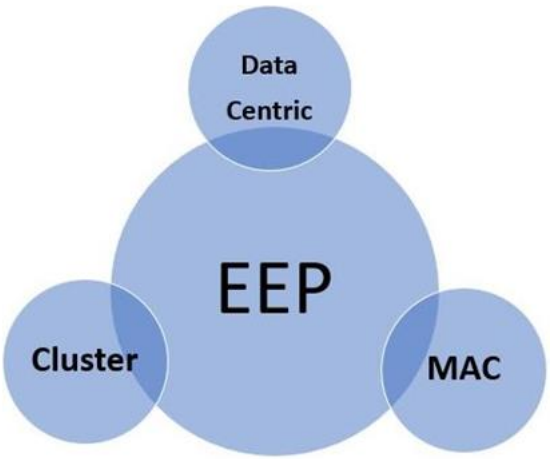


Fig 2. Types of EEP

A. Cluster-Based Protocols: [4,5] Here the nodes are classified into clusters to enhance the EE and scalability of the network, common examples are:

- LEACH: LEACH Stands for Low Energy Adaptive Clustering Hierarchy Protocol. It was designed to provide an improved life span to the physical objects. It works on Time Division Multiplexing, it reports the data to a node called a sink and also partitions the nodes into clusters and cluster heads. The Cluster head creates and maintains the schedule of TDMA. The cluster nodes and cluster heads transmit the data.[6,7]
- HEED: This EEP combines the techniques of randomization and determinism in an aggregation of data. It considers the residual energy and the proximity of cluster heads, to reduce high energy nodes with cluster heads.[8,9]

B. Data-Centric Protocols: [10,11] These EEP's designed to make data dissemination and retrieval efficient, and conservation of energy is done on the propagation of data. Its examples are:

- Directed Diffusion: This EEP uses the user interest in data-driven and gradient in conserving the energy.[12,13]
- SPIN: Sensor Protocol for Information via Negotiation is an EEP, which uses a mechanism called query-response to reduce energy consumption.[14,15]

C. MAC Protocols: [16-21] Medium Access Control Protocols are used to control the communication medium, the sensor nodes communicate via schedules, reduce idle nodes, and lower the number of collisions, its common examples are:

- S-MAC: Sensor MAC, uses a duty cycle to save energy by synchronizing sensor nodes with idle nodes i.e. Active nodes and idle nodes. A mechanism of contention window is used with sleep schedules to save energy consumption.
- T-MAC: These EEPs reduce energy consumption by employing the low duty cycles, idle nodes are in sleep mode

Significance of EEP : Energy-efficient protocols play a crucial role in various domains, particularly in the context of technology and communication systems. The EEPs are designed to enhance the longevity and sustainability of the network, lower energy consumption and achieve reliable communication. The significance of energy-efficient protocols can be

understood from several perspectives:

i) **Sustainability and Environmental Impact**: With the growing concern over climate change and environmental degradation, reducing energy consumption has become paramount. Energy-efficient protocols help minimize the energy required to operate devices, networks, and systems, leading to lower carbon emissions and a smaller ecological footprint.

ii) **Extended Battery Life**: In the realm of mobile devices and wireless sensor networks, energy-efficient protocols can significantly extend the battery life of these devices. This is crucial for devices that are difficult to recharge frequently, such as IoT sensors, remote environmental monitoring devices, or even smartphones and laptops.

iii) **Cost Savings**: Energy-efficient protocols can directly translate into cost savings, especially for large-scale systems like data centers or industrial operations. By reducing energy consumption, businesses can lower their electricity bills and operational expenses.

iv) **Improved Reliability**: In some cases, energy-efficient protocols can improve the reliability of communication systems. For instance, in wireless networks, reducing energy consumption can reduce the risk of signal interference and enhance the overall performance of the network.

v) **Resource-Constrained Environments**: Energy-efficient protocols are essential in resource-constrained environments, where power sources are limited or access to energy is challenging. This is particularly relevant in developing regions or remote areas where electricity supply is unreliable.

vi) **Scalability**: Energy-efficient protocols are crucial for scaling up technology and communication systems. As the number of connected devices and users increases (e.g., in the context of the Internet of Things), energy efficiency becomes even more critical to handle the higher demand without overloading the power infrastructure.

vii) **Regulatory Compliance**: In some cases, energy-efficient protocols may be mandated by regulations or industry standards. Compliance with such requirements ensures that companies and technologies align with energy conservation goals.

viii) **Technological Advancements**: The development of energy-efficient protocols often drives technological advancements and innovations. Researchers and engineers continually strive to create more efficient solutions, leading to new discoveries and improvements in various fields.

ix) **Global Impact**: Considering the vast proliferation of technology and communication systems worldwide, the adoption of energy-efficient protocols can have a significant global impact on energy consumption and environmental preservation.

Some lacunae in energy-efficient protocols research:

a) Cross-Layer Optimization: Energy efficiency often requires optimization across different layers of the communication stack, including physical, MAC, network, and application layers. Various studies using the cross-layer approach in the literature have witnessed the emphasis given to physical layer, link layer, and network layer. Haapola et al. [22]
b) Long-Term Sustainability: Many energy-efficient protocols are designed with the current technology landscape in mind. Research should consider the long-term sustainability of these protocols as new technologies emerge. [23]
c) Multi-Objective Optimization: Energy efficiency is often just one of many objectives. Research could focus on multi-objective optimization, considering factors like throughput, latency, fairness, and reliability alongside energy

consumption.[24]

d) Real-World Implementation and Validation: While there have been many proposed energy-efficient protocols in literature, there's often a gap between theoretical performance and real-world implementation. Research should focus on validating these protocols in practical scenarios, considering factors like hardware limitations, network dynamics, and varying environmental conditions.[25]

Characteristics of EEP:

- Optimize the routing by forwarding the efficient data,
- Using the duty cycle to balance the consumption of energy,
- Schedule the idle nodes in sleeping mode,
- Aggregating data to lower the transmission which can be redundant.
- EEPs must be adaptable to the conditions of network during the deployment.
- Cluster based EEPs can be adapted to ensure improved efficiency with respect to energy consumption and wastage.
- The behavior of EEPs needs to be adaptive to provide Quality of Service during the operational period also ensuring the synchronization to the specific slot of time of operation.

II. Conclusion

As the WSN is accepted widely and the number of physical objects like nodes is increasing rapidly, the long life span of the system can be achieved by ensuring EEP for the communication of physical objects. There's a need to develop such Energy Efficient Protocols which provide sustainable WSNs with reliable ways of communication. Energy-efficient protocols play a crucial role in promoting sustainability, reducing costs, enhancing reliability, and driving technological advancements. By embracing and implementing these protocols, we can create a more sustainable and eco-friendly technological landscape for the future.

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