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A Comparative Analysis of Leach and DEEC WSN Routing Protocols Using MATLAB

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Abstract

Recent developments in wireless sensor networks (WSNs) have given rise to a number of routing protocols created especially for sensor networks where power consumption is a key consideration. Due to their battery-powered nature, Sensor Nodes (SNs) in WSNs are constrained in terms of computational capacity, transmission distance, and energy. Since these SNs cannot be recharged when placed in hostile environments where reachability is impossible, protocols for WSNs should be created with consideration for energy usage. Wireless sensor network routing methods are in charge of preserving the network's pathways and ensuring dependable multi-hop communication. The energy-efficient routing methods LEACH and DEEC in WSNs were described in this study.

Keywords – WSN, DEEC, AI, LEACH and Network.

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a network of small, autonomous devices called sensors that are equipped with wireless communication capabilities. These sensors are distributed in the physical environment and work together to monitor, collect, and transmit data from the surrounding environment. The primary purpose of WSNs is to gather information about the physical world, such as temperature, humidity, pressure, motion, sound, light, and other environmental parameters [1].

WSNs are typically composed of several sensor nodes that communicate wirelessly with each other and, in some cases, with a central base station or gateway. Each sensor node is equipped with one or more sensors to measure specific physical parameters, as well as a processing unit, wireless transceiver, and power source (e.g., battery or energy-harvesting mechanism) [2].

WSNs find application in various domains, including:

- Environmental Monitoring: Monitoring parameters like temperature, humidity, air quality, and pollution levels in forests, oceans, or urban areas.
- Industrial Automation: Controlling and monitoring industrial processes, ensuring safety, and optimizing energy consumption [3].
- Smart Agriculture: Monitoring soil conditions, weather, and crop health to improve agricultural practices.
- Healthcare: Enabling remote patient monitoring, tracking vital signs, and assisting in medical diagnosis [4].
- Structural Health Monitoring: Monitoring the condition and integrity of bridges, buildings, and other infrastructure.
- Home Automation: Creating smart homes with energy-efficient systems, home security, and appliance control.

Overall, WSNs play a crucial role in the Internet of Things (IoT) ecosystem, providing real-time data from the physical world, enabling smart and efficient systems, and facilitating advancements in various domains [5].

II. KEY COMPONENTS

A wireless sensor network (WSN) is a network of small, autonomous devices called sensors that are equipped with wireless communication capabilities. These sensors are capable of gathering and transmitting data from the environment they are deployed in. WSNs are used in various applications, including environmental monitoring, industrial automation, healthcare, smart agriculture, and home automation, among others [6].

Key components of a wireless sensor network:

Communication: Wireless communication is essential for WSNs as it allows sensors to transmit data to a central node or directly to a base station. The communication protocols used in WSNs must be energy-efficient to prolong the sensor nodes' battery life.

Network Topology: WSNs can be deployed in different network topologies, such as star, mesh, tree, or hybrid configurations.

Gateway/Base Station: In many WSN applications, there is a central node or gateway that acts as a sink for the data collected by sensor nodes [7].

Data Processing and Analysis: The data collected by the sensor nodes can be processed and analyzed at different levels. Some simple processing may be performed at the sensor node itself to reduce data transmission, while more complex analysis may be carried out at the gateway or a remote server.

Energy Efficiency: One of the critical challenges in WSNs is the limited power source for individual sensors. To extend the network's lifetime, energy-efficient protocols and techniques are employed to minimize power consumption and optimize communication [8].

Security: WSNs often deal with sensitive data, and security is crucial to prevent unauthorized access and ensure data integrity and confidentiality.

Self-Organization: In many cases, WSNs are deployed in dynamic and unpredictable environments [9].

III. WIRELESS SENSOR NETWORKS (WSNS) PROTOCOLS

WSNs play a significant role in the Internet of Things (IoT) ecosystem, as they enable seamless connectivity and real-time data gathering from physical environments. However, the design and deployment of WSNs require careful consideration of various factors, including the application requirements, energy constraints, and communication protocols [10].

Wireless Sensor Networks (WSNs) utilize various protocols to enable efficient communication and coordination among the sensor nodes. These protocols are designed to address the specific challenges posed by resource-constrained sensor nodes, such as limited power, processing capabilities, and memory. Here are some key protocols commonly used in WSNs:

Medium Access Control (MAC) Protocols:

Low-Energy Adaptive Clustering Hierarchy (LEACH): A popular clustering-based MAC protocol, where sensor nodes organize themselves into clusters with a rotating cluster head. The cluster head aggregates data from member nodes and communicates with the base station, reducing overall energy consumption [10].

Time Division Multiple Access (TDMA): This protocol assigns specific time slots to each sensor node for transmission, ensuring collision-free communication and efficient power management.

Routing Protocols:

Directed Diffusion: A data-centric protocol where data is disseminated towards the base station using directed gradients based on interest and data requests.

Dynamic Source Routing (DSR): Another reactive protocol that maintains source routes in the data packets to be followed by intermediate nodes.

Transport Protocols:

User Datagram Protocol (UDP): Often used in WSNs for its low overhead and simplicity, as real-time data delivery is critical in many applications.

Constrained Application Protocol (CoAP): Designed specifically for constrained IoT devices, it enables efficient communication with low overhead.

Security Protocols:

Elliptic Curve Cryptography (ECC): A lightweight cryptographic algorithm used for secure communication with minimal processing and memory requirements.

TinySec: A link-layer security protocol designed for resource-constrained devices in WSNs.

IV. ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

Routing protocols in Wireless Sensor Networks (WSNs) are responsible for establishing and maintaining communication paths between sensor nodes and the base station (or gateway) to efficiently transmit data. Since sensor nodes are often resource-constrained with limited power and processing capabilities, routing protocols in WSNs need to be designed to minimize energy consumption, prolong network lifetime, and optimize data delivery [11].

Dynamic Source Routing (DSR): Another reactive protocol that maintains the source route in the data packets to be followed by intermediate nodes. This reduces the overhead of route discovery at the cost of increased packet size [12].

Hierarchical Routing Protocols:

Hierarchical routing protocols organize sensor nodes into different hierarchical levels or clusters to improve energy efficiency and reduce communication overhead [13].

V. LEACH

The Low-Energy Adaptive Clustering Hierarchy (LEACH) is a popular hierarchical routing protocol designed specifically for Wireless Sensor Networks (WSNs). It aims to reduce energy consumption and prolong the network's lifetime by forming clusters and rotating cluster heads among sensor nodes. LEACH is a self-organizing and adaptive protocol that helps in efficient data aggregation and communication in WSNs [14].

LEACH Advantages:

LEACH significantly reduces energy consumption and prolongs network lifetime compared to flat routing protocols.

The cluster-based approach enables efficient data aggregation and reduces redundant data transmission.

The adaptive nature of LEACH allows the network to adjust dynamically to changes in node conditions and energy levels.

LEACH Limitations:

Since the cluster head selection process is probabilistic, it may lead to uneven distribution of energy consumption in certain rounds.

The protocol does not consider node mobility or the network's changing topology, which can impact the overall performance.

LEACH may not be suitable for applications requiring real-time data transmission due to the randomized nature of cluster head selection.

Despite its limitations, LEACH has been an influential protocol and served as a basis for the development of many other energy-efficient routing algorithms for WSNs. Researchers continue to work on improving the protocol's efficiency and addressing its shortcomings to enhance its applicability in various WSN scenarios.

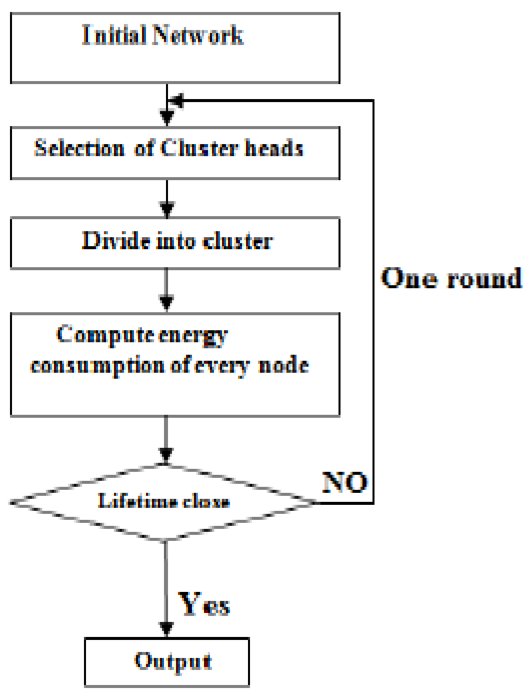

Fig.1. Flow chart of LEACH protocols.

VI. DISTRIBUTED ENERGY- EFFICIENT CLUSTERING (DEEC)

Algorithm For heterogeneous WSNs, DEEC is a well-known energy-efficient protocol. The field is organised by many clusters in DEEC. Each cluster has a CH and a few sensor nodes. Receiving data from sensor nodes in a cluster and sending it to the BS is the responsibility of the CH. A probability function is generated to designate the node as Cluster Head (CH). The residual energy and network average energy are used to define this function. This function calculates the ratio of each node's residual energy to the network's average energy, and it does so for each node in a cluster.

A node with a higher computation value than other nodes has a better probability of being chosen as a CH. In WSN, CHs are randomly selected. For this, a cluster head selection technique is used. The primary responsibility of CH is to gather data from a cluster and transfer it to BS. Additionally, it is presumable that the initial energy levels of each WSN node vary, and that freshly inserted or energy-harvested nodes have a higher beginning energy level than older nodes. It should be noted that the ratio between each node's residual energy and the network's average energy affects the likelihood of CHs.

The DEEC method is a distributed clustering technique created to maximise energy efficiency and increase network lifespan in WSNs. By grouping sensor nodes into clusters with elected cluster chiefs, it seeks to accomplish effective data aggregation and transmission.

After each round, new cluster heads are chosen, so the burden of communication and data aggregation is distributed among different nodes throughout the network [15].

The DEEC algorithm, like LEACH, leverages the benefits of clustering to reduce communication overhead, aggregate data, and extend the network's lifetime. However, the specific details and energy-efficient mechanisms may vary depending on the implementation and the research behind the algorithm.

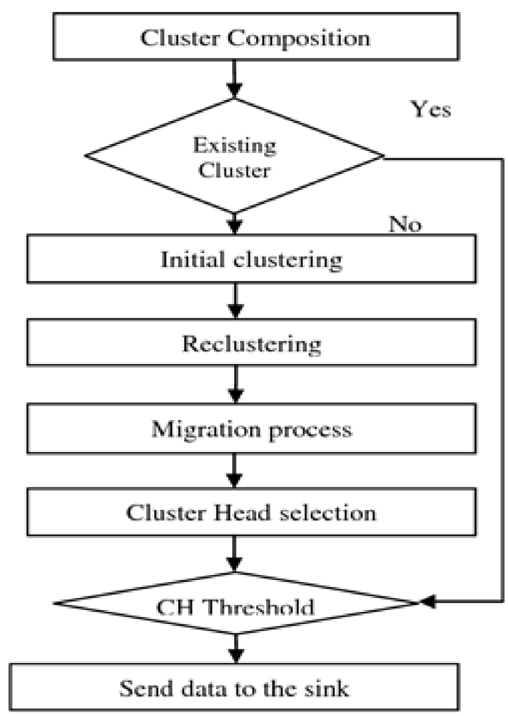

Fig.2. Flow chart of DEEC protocols.

Mathematical Modelling-

$$f(p) = \begin{cases} \frac{p}{1 - p * (rmod(1/p))}, & if \ n \in g \\ 0, & n \nexists g \end{cases}$$

Where p is number of % cluster Generation, r is node across cluster election rounds, $(rmod(1/p))$ is shows multiple round cycle and g is a Sets.

Now routing distance are mention in terms of E_{fs} (free space attenuation of data) and E_{mp} (Multipath attenuation model)

$$dth = \frac{\sqrt{Efs}}{\sqrt{Emp}}$$

Also WSN routing batter life time $\mathbf{t_{lifetime}} = \frac{E}{P}$

Where P is a power and E initial energy of battery.

VII. RESULT AND SIMULATION

MATLAB simulator is used to study the LEACH and DEEC routing protocols in WLAN-based WSNs. These protocols perform better, as evidenced by earlier experiments, and they operate well with WLAN-based WSNs. The efficacy of several protocols will be evaluated in this section in terms of latency, throughput, and network load in small-, medium-, and large-scale networks. A small network consists of 100 nodes, whereas a large network has 200 nodes. Figures demonstrate the visualization of the simulation model. The general parameters for simulation conditions are shown in Figure.

LEACH Routing protocols results

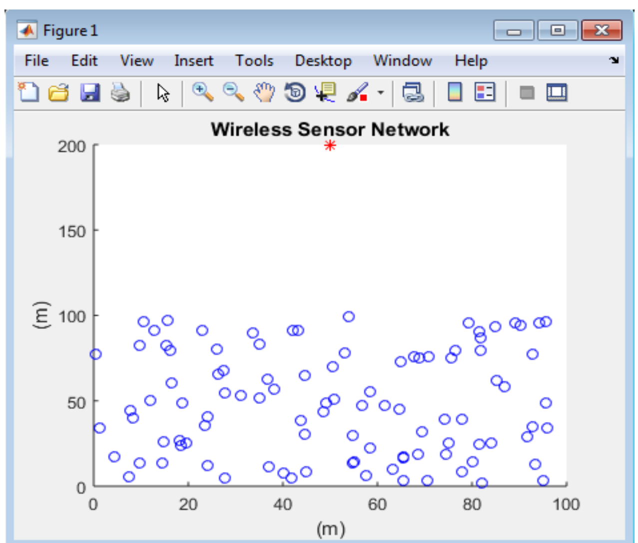

Fig.3 Node Generation.

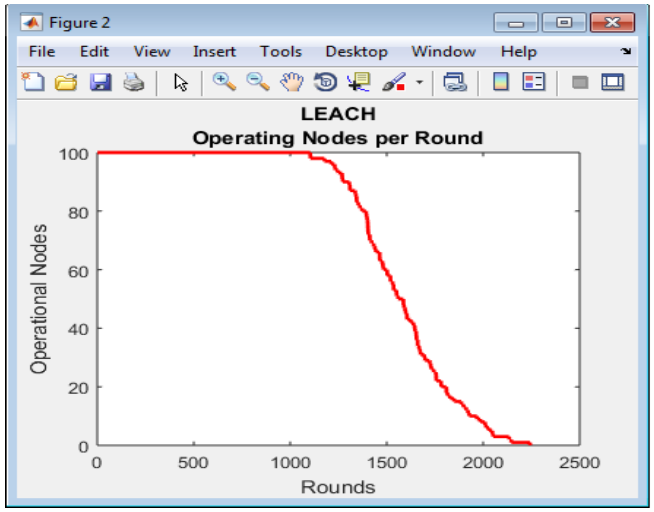

Fig.4 Operational node and Rounds.

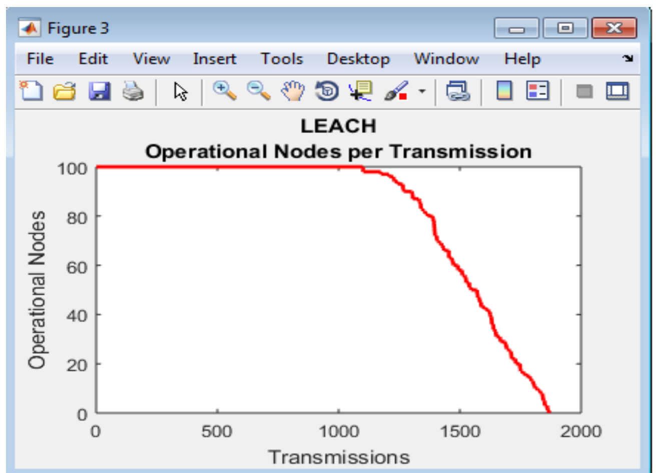

Fig.5 Nodes and Transmission of Data.

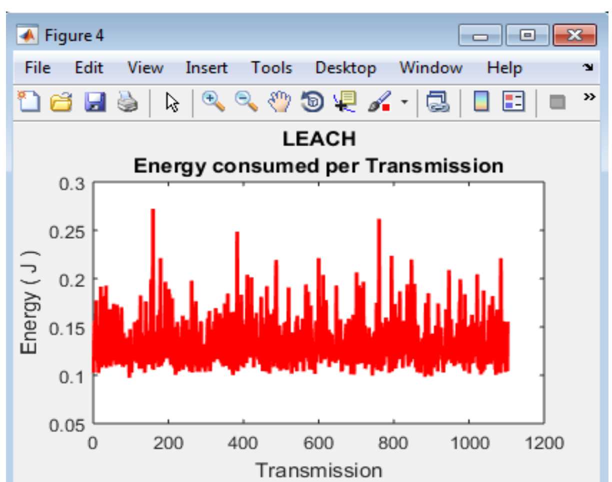

Fig.6 Energy Consumption.

DEEC Routing Protocols Results-

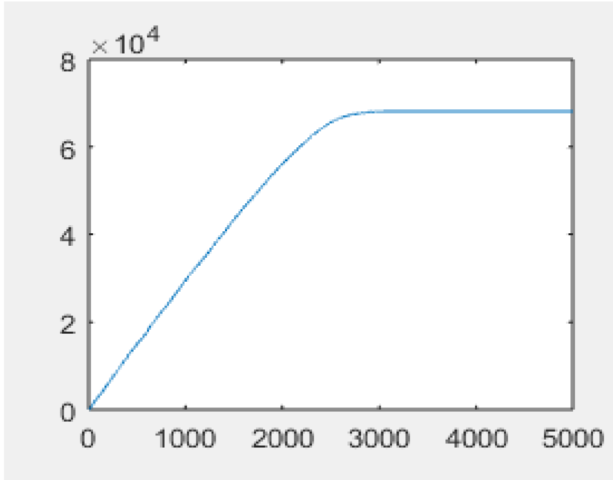

Fig.7 Transmission of Data in terms of throughput.

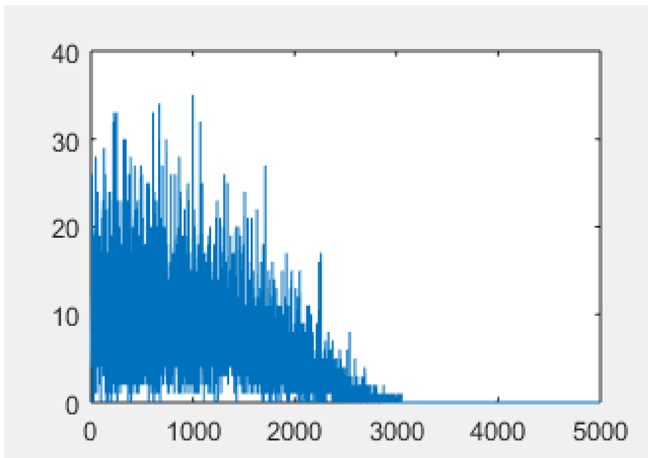

Fig.8 Energy Consumption in DEEC protocol.

Three enhancements are incorporated into the DEEC protocol in this study to increase its efficacy, efficiency, and stability for WSNs. DEEC, in its simplest form, is an adaptive energy-efficient technique to design the shift in the likelihood of sensor nodes becoming CHs. Few adjustments are suggested in this study to strengthen the protocol's reliability, capability, and robustness. The packet lifespan and energy consumption problems with DEEC are the focus of these changes. As a result, the scaling parameter and neighborhood information concepts have been incorporated into the DEEC protocol.

A modified threshold probability Equation is also suggested among them to choose the CH effectively. The suggested protocol's experimental findings are contrasted with those of the LEACH and DEEC protocols. The proposed procedure outperforms the others in terms of effectiveness.

VIII. CONCLUSION

The lifespan of wireless sensor networks is a crucial characteristic that should be taken into account by routing systems. However, the majority of suggested routing protocols in the literature concentrated on reducing the energy consumption of each sensor node in order to lower the mean amount of energy spent and did not balance the energy consumption in the network in order to lengthen network lifetime. This paper's goal was to present a mathematical model for our LEACH and DEEC routing protocols for sensor networks, which improve protocol for maximizing network lifespan.

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