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Design and Analysis of Enhanced LEACH based Energy Routing Protocol for Wireless Sensor Network

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ABSTRACT

In recent times, wireless sensor networks, or WSNs, have attracted a lot of attention because of their extensive use in a variety of fields, such as industrial automation, healthcare, and environmental monitoring. Energy efficiency is a major problem for WSNs since sensor nodes frequently run on batteries and have little energy available. Effective routing techniques are essential for extending the life of the network and guaranteeing dependable data transfer. This work focuses on the performance analysis and numerical modeling of a new routing strategy that combines machine learning approaches to improve WSN energy efficiency. The suggested routing algorithm optimizes energy consumption and overall network performance by adjusting its recommendations in real-time in response to environmental and network variables. We assess this machine learning-based routing protocol's performance using large-scale numerical simulations, contrasting it with conventional routing protocols and emphasizing its possible advantages in terms of energy efficiency and dependable data delivery. We investigate a variety of situations in our simulations, taking into account different network topologies, traffic patterns, and environmental factors. We evaluate many measures, including energy consumption, network lifetime, packet delivery ratio, and end-to-end delay, in order to offer a thorough evaluation of the efficacy of the machine learning-based routing protocol. The outcomes show how energy-efficient the protocol is, guaranteeing long-lasting sensor nodes and reliable data transfer while adjusting to changing network conditions.The results of this study highlight how machine learning approaches can completely change how routing protocols are designed and optimized in wireless sensor networks with limited energy. This research helps to construct sustainable and dependable WSNs by enhancing energy efficiency and network performance, which makes it easier to deploy sensor networks in crucial applications.

Keywords-WSN, LEACH, LEACH-C, Network Life Time, Base Station, Sensor Node

1. INTRODUCTION

Wireless Sensor Networks (WSNs) have witnessed remarkable growth in recent years, spurred by their extensive applications in diverse fields, including environmental monitoring, industrial automation, healthcare, and smart cities. These networks comprise a multitude of tiny sensor nodes that collaborate to collect and transmit data to a central sink or base station. While WSNs offer unprecedented capabilities for real-time data acquisition and monitoring, they face several inherent challenges, chief among them being the limited energy resources of the sensor nodes. Energy efficiency is a paramount concern in WSNs, primarily due to the battery-powered nature of sensor nodes. Once deployed, sensor nodes are often inaccessible or impractical to recharge or replace, making energy conservation a critical factor for network sustainability and longevity. Prolonging the operational lifetime of these nodes while maintaining reliable data transmission is a fundamental challenge that has drawn the attention of researchers and practitioners alike. Routing plays a pivotal role in the energy efficiency of WSNs. Routing protocols dictate how data packets are forwarded from source nodes to the destination, determining the paths through which information travels within the network. Conventional routing algorithms in WSNs, such as LEACH (Low-Energy Adaptive Clustering Hierarchy) and AODV (Ad Hoc On-Demand Distance Vector), have been designed with the goal of conserving energy and extending the network's lifetime. These protocols, however, often operate under static assumptions, neglecting the dynamic and unpredictable nature of real-world deployment environments.In contrast to traditional routing methods, machine learning-based approaches have gained prominence as a means to address the energy efficiency challenge in WSNs. Machine learning techniques offer the promise of adaptability and responsiveness to changing network conditions and data traffic patterns. These methods can exploit historical data and real-time inputs to make intelligent routing decisions that optimize energy consumption, prolong the network's lifetime, and ensure reliable data delivery.

This research is motivated by the pressing need to explore and evaluate the potential of machine learning-based routing algorithms in enhancing the energy efficiency of WSNs. The fundamental question driving this study is whether machine learning techniques can indeed lead to substantial improvements in network performance and energy

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conservation when applied to wireless sensor network routing. To answer this question comprehensively, we embark on a numerical simulation and performance analysis journey.

1.1. Research Objectives

The primary objective of this research is to design, implement, and rigorously evaluate a machine learning-based routing protocol tailored for energy-efficient operation in wireless sensor networks. This protocol will leverage machine learning models and algorithms to adaptively make routing decisions based on real-time environmental conditions and network states. To achieve this overarching goal, the specific research objectives can be summarized as follows:

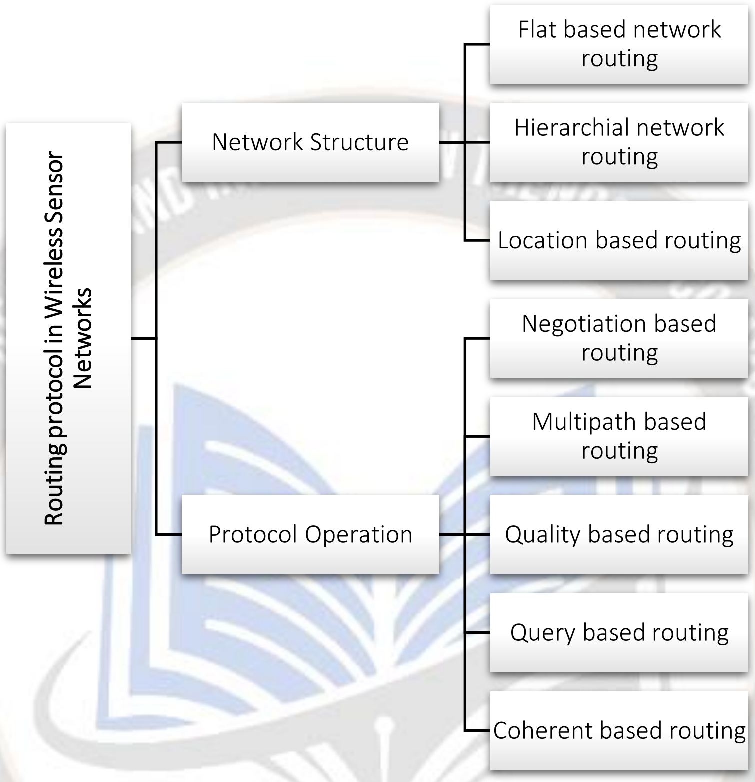

Figure 1.1 Routing protocols in Wireless Sensor Networks

Develop a machine learning-based routing algorithm for wireless sensor networks that can dynamically adjust routing decisions to optimize energy consumption, network lifetime, and data delivery reliability .Conduct extensive numerical simulations under diverse network scenarios, including varying topologies, traffic loads, and environmental factors, to evaluate the performance of the proposed machine learning-based routing protocol. Compare the performance of the machine learning-based protocol with that of traditional routing protocols widely used in WSNs, such as LEACH and AODV, in terms of energy consumption, network lifetime, packet delivery ratio, and end-to-end delay. Analyze the adaptability of the machine learning-based routing protocol to different application domains and network conditions, highlighting its potential advantages in real-world deployments. Provide insights into the practical implications of adopting machine learning-based routing algorithms in energy-efficient wireless sensor networks, considering scalability, resource constraints, and ease of implementation.

In summary, this research endeavors to explore the potential of machine learning-based routing protocols in enhancing the energy efficiency of wireless sensor networks. By conducting numerical simulations and performance analyses, we aim to provide valuable insights into the feasibility and benefits of adopting machine learning techniques in this context. The subsequent sections of this paper will delve into each aspect of our research, offering a thorough investigation into the role of machine learning in shaping the future of energy-efficient wireless sensor network routing..

The description provided introduces a hierarchical clustering and routing approach used in wireless sensor networks, specifically referencing the LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol. In this system, nodes within a local area network (LAN) form clusters, with each cluster having a designated cluster head. Hierarchical routing is employed to extend the network's lifespan and manage energy consumption effectively. Here, we will break down the key concepts and characteristics outlined in the description.Cluster formation involves the creation of local

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cluster groups within a LAN, with each cluster comprising multiple nodes and one designated as the cluster head. This organization facilitates efficient data aggregation and routing within the network. The cluster head node assumes pivotal responsibilities in data management and processing, collecting data from all other nodes within its cluster and performing tasks like data aggregation before forwarding the processed data to a remote baseline or base station. However, cluster head nodes consume more energy and resources compared to regular nodes, and their failure can disrupt data aggregation and routing functions across the entire cluster. To address energy concerns, mechanisms like LEACH employ random rotation of cluster head positions to distribute the energy load, ensuring that nodes take turns being cluster heads. Load sharing among nodes within a cluster is facilitated through mechanisms like Time-Division Multiple Access (TDMA) scheduling, which efficiently allocates time slots for data transmission while minimizing collisions and optimizing energy usage. The operation of clusters in LEACH occurs in rounds, comprising setup and steady-state phases, where cluster formation, selection of cluster heads, and data collection, aggregation, and transmission are executed. Local coordination manages cluster setup and operation, with cluster head selection randomized to reduce the need for global communication and coordination. Efficient use of radio resources is optimized to minimize energy wastage, assuming nodes have radios with adjustable power levels. Furthermore, cluster head rotation ensures fairness in leadership distribution, allowing nodes to take turns being cluster heads and optimizing node scheduling for data transmission and reception within the cluster.In summary, LEACH is a hierarchical and energy-efficient routing protocol designed for wireless sensor networks. It employs randomized cluster head selection, TDMA scheduling, and data aggregation to conserve energy and prolong the network's operational lifespan. By distributing the energy load among nodes and implementing local coordination, LEACH addresses the critical challenge of energy efficiency in wireless sensor networks

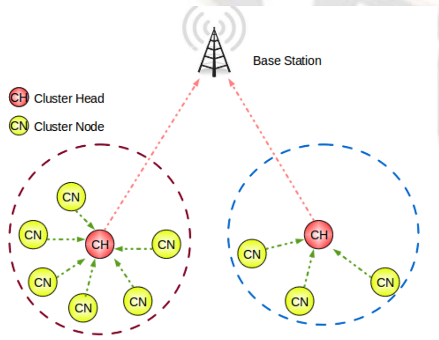

Figure 1.2 Illustration of LEACH Protocol

Nodes that aren't cluster heads can only connect with the cluster head using TDMA, and only on the schedule that the cluster head specifies. Only within their allotted time period do they need to be connected to the cluster head's radios.

2. LITERATURE SURVEY

As of 2020, Anik Kumar Saha [1] One of the technologies that is developing the fastest for internet data transmission is Wi-Fi Sensor Networks, or WSNs. WSN is currently involved in almost every field of science and technology. The numerous tiny nodes that make up the WSN are responsible for sensing, data processing, aggregation, compression, and transmission. The small size of the sensor nodes limits the power of the little battery. The primary challenge facing WSNs is figuring out how to maximize the limited battery power of these networks to increase their useful lifetimes while reducing energy consumption. In contrast, WSN has already put in place a variety of intricate clustered routing algorithms in an effort to save energy. The main goal is to enhance the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol by implementing a new clustering routing topology. Our suggested model for locating cluster heads follows the same steps as the traditional Leach methodology. The network has been deployed in every industry, despite the fact that its complete size has been split up into several rectangular distributed zones. This article examines the outcomes of simulating the R-LEACH process in MATLAB.

(Haibo Liang, Jianchong Gao, Li, and Shuo Yang, 2019) [2] This study shows how to enhance routing methods. in order to guard against an unbalanced distribution of cluster heads. The ideal number of cluster heads is first estimated using the total energy consumed in each round. This would therefore make the cluster head the basis of the Voronoi diagram. A cluster that minimizes the amount of energy consumed between clusters is formed by the nodes in the same Voronoi diagram. By utilizing the cluster head adjacent to the base station as part of an anti-colonial strategy, the multihop routing protocol is ultimately made simpler. Based on MATLAB simulation results, the protocol may significantly increase the energy efficiency per unit node continuously and prolong the lifetime of WSNs in comparison to the LEACH protocol. In this instance, an energy-consumption-only strategy is suggested. The Node (FND) had a 127 percent greater first death rate than LEACH, LEACH-C, and SEP. (Karan, Kunal, and K. Agarwal, Agarwal, 2018) [3] Wireless sensor networks (WSNs) have become one of the most potent and efficient means of transmitting and receiving data in the contemporary scientific and technological world. Numerous industries, including manufacturing, environmental monitoring, pharmaceuticals, and more, are seeing rapid growth in the use of WSNs. In order to collect valuable data, a large number of small sensor nodes are scattered throughout the WSN area. These nodes are therefore helpful for monitoring a range of environmental variables. The sensor node processes data in a variety of ways, including encoding, receiving, and transmitting. The little nodes significantly cut down on the tiny battery's power. Therefore, in order to increase the network's usable life, it is imperative that this finite resource be used carefully. Consequently, the Low Energy Adaptive Hierarchical Clustering (LEACH) methodology was created. The node is elevated to the role of cluster head (CH) in this protocol. The random selection of CHs leads to the creation of a resource-saving method. The

LEACH method is assessed in this study using a MATLAB simulation, and the results are analyzed for future application. Alhmiedat, T. (2017) [4] The challenge of high power consumption arises for WSN-based environmental monitoring systems because of their multi-hop data transfer. A proof of concept implementation demonstrates that grouping environmental sensor nodes using an algorithm for clustering results in much lower power consumption. This contributes to resolving the energy depletion problem. The design and installation of an eight-sensor WSN environmental monitoring network that covers a 1 km2 area in Tabuk, Saudi Arabia, is covered in this study. A number of real experimental investigations have been conducted to prove the viability of the suggested environmental monitoring program.

(Z. Li, M. Junaid, Y. Lu, J. Zou, H. Liang, 2019) [5] We propose a fluid multi-level strategy to optimise the support vector retransmission (SVR) while considering the leakage risk. This article is based on particle swarm optimization (PSO). Furthermore, there were two primary objectives. We will start by developing a multi-tiered methodology for evaluating leak risk. Using the PSO algorithm, PSO-SVR will be utilized to perform dynamic risk assessment in real time and analyze the outcomes of risk assessments. In order to create a multi-level risk assessment framework, we use the characteristics and legal phenomena associated with the parameters of acquisition and loss as an indicator in this study. Second, a risk assessment model is constructed using the fluctuation theory. Ultimately, a PSO-enhanced SVR algorithm is used to optimize the SVR model parameters C and g. This solves the challenge of choosing parameters like the sensitivity coefficient, kernel function, and penalty factor c in the traditional SVR model, improves model accuracy, and enables more accurate dynamic risk assessments in real time. This paper proposes an algorithm that accomplishes two goals. As an engineering example, the results show that the PSO-SVR model can achieve 99 percent accuracy, with a high degree of convergence that is evidently greater than the multi-layered perceptron neural network model. Liang, H. (2019) [6] This study suggested the use of data mining sand plug fracturing as an early warning system. Time series analysis is used to construct a precocious alerting model of a double logarithm sand plug and to increase the early warning accuracy of a fracturing hazard warning model. This is due to two factors: GRNN's primary goal is to increase time-domain analytics forecasting accuracy. Using a novel affinity propagation (AP) clustering technique, monitoring data is clustered to enhance the correlation rate between fracturing risk and sand plug. The ultimate phase involves testing the on-site danger alert model to see if it is dependable. This idea is used in remote monitoring to carry out intelligent online risk monitoring.

3. PROPOSED METHODOLOGY

To begin the simulation, we used a set of predefined parameters in this study. After the necessary number of cycles have been completed, the data are gathered and analysed. The results are used to show the diagrams, while the diagrams themselves are used to explain the results. Finally, we compared our findings to similar studies in the literature.

A Centralized LEACH and an Improved LEACH Sensor nodes have multiplied tremendously in terms of measurement and transmission/reception. Hundreds of network applications may be installed at the same time. The limited power supply of sensor nodes necessitates that they be used effectively to extend the life of the network. The routing protocol utilised has a significant impact on this performance. Because the base station is sending more, the remote nodes expire sooner. In order to transmit their signal, they use up energy. Using clustering techniques, data from far nodes can be transmitted to their cluster heads. As a result, we use less electricity. The end goal is to keep a long-term network active and functional. Some of the routing protocols implemented are similar to LEACH, DEEC, and SEP, as well as TEEN. In this regard, ILEACH is one of the most common and advanced methods. The multi-hop technique is an addition to the ILEACH protocol. The relationship between the cluster's leaders. Each cluster head receives packets from its nodes and then passes them forward to the next cluster head in turn. The cluster heads tree identifies this as the object under discussion. The utilisation of several hops in the transmission of data saved from the base station. Route packets between cluster Head and the sink using a heuristic search for the most efficient path, based on two layers of clustering. The ILEACH Protocol makes use of the weighting definition to determine which nodes are eligible to serve as CHs (Cluster Heads). The possibility of being weighted is as follows

$$\mathrm{P}_{\text{nonual}} = \frac{P}{1+\mathrm{a}\times \mathrm{m}}$$

$$P_{\text{advanced}} = \frac{P}{(1+\alpha X m)} \times (1+\alpha)$$

m is the percentage of advanced nodes, and is the additional power factor for advanced and advanced standard nodes as well as normal nodes. All packets are routed in the most energy-efficient manner possible by each hop in the proposed enhanced static node network of the proposed improved protocol (sink). In order to keep individual nodes from wasting energy, the network as a whole should be kept as efficient as possible.

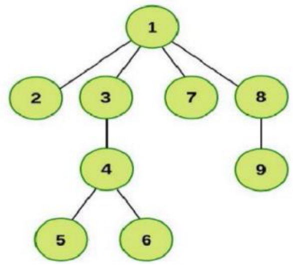

Figure 3.1 Process of Forming Tree Using Proposed Methodology

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The following nodes should be added to the list of requested improvements to the protocol: values or characteristics: Every node, no matter which cluster head or sink it will deliver your packet to, is considered a parent. Nary tree arrangement is based on the node's parent and this information. For every packet transmitted out of this node, an estimated amount of energy will be lost across the overall network. Transferring data across a network node will result in a loss of energy for other nodes; saving this value gives you an estimate of that loss. The pseudo code cluster head energy loss array displays this variable. The best way to get cluster head, u, is to use the following algorithm. The best way to go. For that node, Ep(v) is a qualifying number of parents. In relation to that particular node. There is an energy loss for every node that is closer to sinking in this package in absolute distance (the distance of Euclides) from u than u. Sends her the package. To begin, we arrange the spectra of the cluster heads in increasing order of distance. To determine the energy loss, we need to know the index of the cluster head in the node array, which we will denote by the letter i. In the next step, we'll proceed to the array with the index j, which is between the zeros and one. Everyone in this iteration is considered a child of j. We conclude that j will have the smallest amount of energy loss in the whole network. This energy loss is quantified by adding the node's energy loss. I to j packets have j energy losses, which have already been j-i calculated.

4. RESULT ANALYSIS

In the conducted simulations, several parameters including the number of nodes, the network area, and the initial energy levels of nodes were considered. The study focused on analyzing and comparing various metrics such as the number of nodes that became inactive (dead), the number of nodes that remained active, the volume of data packets transmitted to the central sink node, and the number of rounds required for all nodes to exhaust their energy resources.

The comparative study aimed to evaluate the effectiveness of the proposed methodology in different operational scenarios, and this was achieved through extensive simulation and comparative analysis. This section provides a comprehensive comparison between the suggested algorithm and the currently employed algorithm.

Two distinct scenarios were considered for this comparative analysis, involving 200 and 400 nodes in the network. To facilitate the comparison, we present the results for both test cases:

Test Case 1: Comparison with 200 Nodes: Figures 4.3 and 4.4 provide a detailed comparison of the performance metrics when utilizing 200 nodes in the network. These figures illustrate the outcomes of the proposed heuristic approach augmented with LEACH in contrast to the traditional and improved versions of LEACH.

Test Case 2: Comparison with 400 Nodes: For the scenario involving 400 nodes, the comparison results are presented in Figures 4.1 and 4.2. These figures depict the performance differences among the three algorithms, namely the proposed heuristic approach combined with LEACH, the traditional LEACH, and the improved LEACH.

Across both test cases, the findings consistently demonstrate that the heuristic approach, when integrated with LEACH, surpasses the performance of both the traditional and improved versions of LEACH. This superiority is evident in terms of various metrics, including the number of dead nodes, network longevity, data transmission efficiency, and the number of rounds taken for the nodes to exhaust their energy reserves.In summary, the comparative analysis validates the effectiveness of the proposed methodology, highlighting its ability to outperform existing algorithms, irrespective of the network size. The results underscore the potential benefits of integrating the heuristic approach with the LEACH protocol in optimizing the performance of wireless sensor networks.

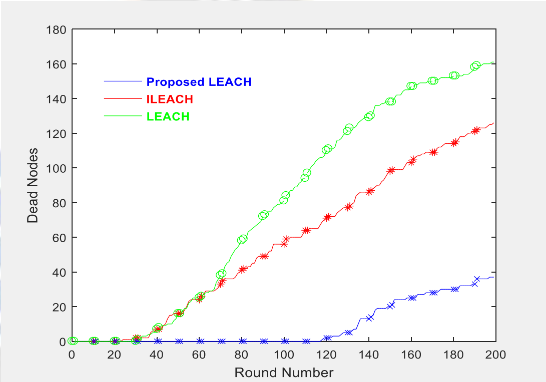

Figure 4.1 Comparative Analysis of Dead Nodes for Proposed System-Test Case-1

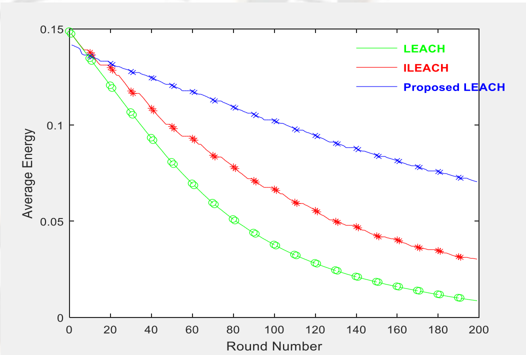

Figure 4.2 Comparative Analysis of Average Energy for Proposed System-Test Case-1

Tables comparing the performance of LEACH, ILEACH, and a proposed protocol based on different parameters are provided below. Based on the number of dead nodes, we compare the performance of the three protocols. After a specified number of rounds, we compare the number of dead nodes for each protocol.

Table 4.1
Comparison of Number of Dead Nodes

Rounds	**Total Dead Nodes**		
	LEACH	ILEACH	**Proposed**
40	12	12	1
80	60	52	2
120	105	70	5
160	137	115	25
200	160	132	41

Table 4.2
Comparison of Average Energy

Rounds	**Average Energy(J)**		
	LEACH	ILEACH	**Proposed**
20	0.128	0.13	0.137
40	0.098	0.108	0.14
80	0.056	0.08	0.117
120	0.039	0.056	0.105
160	0.02	0.044	0.094
200	0.01	0.028	0.075

In Tables 4.1 and 4.2, a comparison of LEACH, ILEACH, and the suggested protocol's performance is presented depending on various factors. The number of dead nodes is used to compare the output of the three methods. We compare the number of dead nodes for each protocol after a predetermined number of rounds has been completed in each protocol. The efficiency of the three protocols is compared using their average energy. We compare the average energy of each node after a number of rounds for each of the three procedures.

5. CONCLUSION & FUTURE RESEARCH

In many situations, wireless sensor networks are dispersed over vast distances. In this context, techniques to enhance WSN management are required. Wireless sensor networks leverage the limited capacity of the battery. Developing protocols for Wireless Sensor Networks is challenging due to the sensor nodes' limited computing capability. Every routing protocol is created to minimize energy consumption and increase network lifespan. To address this problem of energy efficiency, we applied a clustering technique. We introduce the heuristic LEACH as a novel form of the ILEACH protocol that may also be used to increase the efficiency of other clustering techniques. After the first round, the cluster heads are changed to reduce energy use. The protocol routing burden is decreased when the energy level of the cluster head falls below a predetermined threshold. This means that at the start of every round, the cluster head substitution mechanism needs the remaining energy of the cluster head. After 200 rounds, heuristic LEACH discovered 74.5 percent fewer dead nodes than LEACH, and ILEACH found 68.5 percent fewer dead nodes than LEACH. Nodes' energy levels dramatically rose, extending the network's lifespan and increasing its efficiency.

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