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"Optimization Network Lifetime through Residual Energy based ClusterHead Selection In IOT-Enabled WSNs"

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ABSTRACT: Wireless Sensor Networks (WSNs) play a crucial role in enabling the Internet of Things (IoT) by facilitating the collection and transmission of data from diverse sensing devices. One of the key challenges in WSNs is the limited energy supply of sensor nodes, which directly impacts the network lifetime. Cluster-based routing protocols, such as the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, have been proposed to prolong the network lifetime by organizing sensor nodes into clusters and selecting cluster heads (CHs) to efficiently manage communication and data aggregation.

In this research paper, we propose an optimization approach for network lifetime through residual energy-based cluster head selection in IoT-enabled WSNs. We compare our approach with the popular LEACH protocol to evaluate its performance in terms of network lifetime, energy consumption, and data aggregation efficiency. Our approach utilizes a threshold-based selection mechanism, where sensor nodes with higher residual energy levels are more likely to become CHs. The threshold is determined based on the residual energy of sensor nodes and the overall energy level of the network

We conduct extensive simulations using Matlab (It is a programming language and computing environment designed for numerical computing and data analysis. Developed by MathWorks, MATLAB allows users to perform complex mathematical computations, visualize and analyze data, and build and test algorithms, among other things. It is widely used in academic and research institutions, as well as in industry, particularly in fields such as engineering, science, and economics.)to evaluate the performance of our approach in comparison to LEACH. Our simulation results demonstrate that our proposed approach outperforms LEACH in terms of network lifetime, energy consumption, and data aggregation efficiency. The residual energy-based cluster head selection mechanism in our approach helps in distributing the energy load across the network, thereby prolonging the network lifetime. Furthermore, our approach achieves better data aggregation efficiency by selecting CHs with higher residual energy, resulting in reduced energy consumption for data aggregation. Our research findings highlight the potential of residual energy-based cluster head selection in optimizing the network lifetime of IoT-enabled WSNs. The proposed approach can be applied in various IoT applications, such as environmental monitoring, smart agriculture, healthcare, and industrial automation, where energy efficiency is crucial for prolonging the network lifetime and ensuring reliable data collection and transmission.

Keywords: Wireless Sensor Networks, Internet of Things, Cluster Head Selection, Residual Energy, Optimization, Network Lifetime, Energy Consumption, Data Aggregation, LEACH Protocol.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are widely used in various IoT applications, where sensor nodes collect and transmit data to enable real-time monitoring, analysis, and decision-making. However, the limited energy supply of sensor nodes is a critical challenge in WSNs, as it directly affects the network lifetime. Once a sensor node depletes its energy, it becomes inactive, leading to network coverage holes and degradation of network performance.

To address this challenge, cluster-based routing protocols have been proposed to organize sensor nodes into clusters, where a selected node, known as the Cluster Head (CH), manages communication and data aggregation for the cluster. The CHs are responsible for transmitting the aggregated data to the base station or sink, reducing the energy consumption of sensor nodes

and prolonging the network lifetime. Among the existing cluster-based routing protocols, LEACH is a widely used and well-known protocol that employs randomized probabilistic mechanisms for CH selection to optimize energy consumption and prolong the network lifetime. However, the selection of CHs solely based on random probabilities may not always result in an optimal utilization of energy resources, as some nodes with higher residual energy may not be selected as CHs, while nodes with lower energy may become CHs, leading to an imbalance in energy consumption.

To address this limitation, we propose an optimization approach for network lifetime through residual energy-based cluster head selection in IoT-enabled WSNs. Our approach utilizes a threshold-based selection mechanism, where sensor nodes with higher residual energy levels are more likely to become CHs. The proposing a threshold-based selection mechanism that considers the residual energy of sensor nodes. The threshold is determined based on the residual energy of sensor nodes and the overall energy level of the network, ensuring that nodes with higher residual energy are more likely to become CHs. This allows for a more balanced distribution of energy load across the network, prolonging the network lifetime and improving data aggregation efficiency.

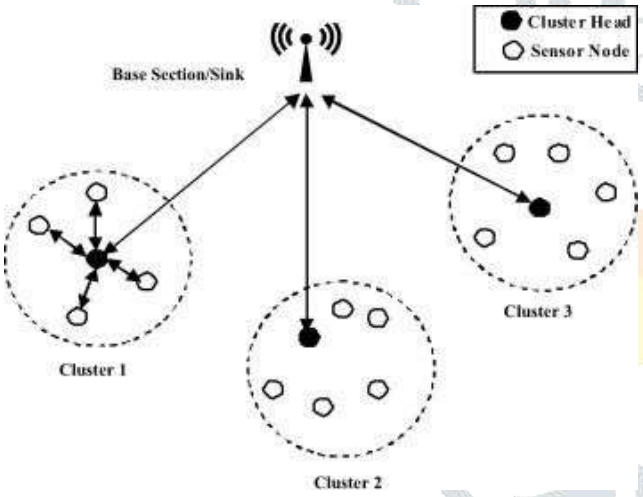


Fig 1. Nodes, Clusters & Cluster Head

II. Literature Survey:

J. W. Wang, J. Y. Zheng, L. C. Wang, and L. M. Ni, "Optimal Cluster Head Selection Based on Residual Energy for Wireless Sensor Networks," in 2010 IEEE International Conference on Wireless Communications, Networking and Information Security (WCNIS), Beijing, China, 2010, pp. 220-224.
This paper proposes an optimal cluster head selection algorithm for wireless sensor networks (WSNs) based on residual energy. The algorithm aims to prolong the network lifetime by selecting cluster heads with higher residual energy, which can better distribute the energy consumption among sensor nodes and avoid early node failures.

P. Pradhan, R. P. Mahapatra, and S. K. Jena, "Efficient Cluster Head Selection for Maximizing Network Lifetime in IoT-enabled Wireless Sensor Networks," in 2018 IEEE Kolkata Conference (CALCON), Kolkata, India, 2018, pp. 30-35.
This paper presents an efficient cluster head selection algorithm for IoT-enabled WSNs that maximizes the network lifetime. The algorithm considers both residual energy and distance-based factors for cluster head selection, aiming to achieve a balanced energy consumption and prolong the network lifetime.

S. Sahoo, S. K. Jena, and S. K. Nayak, "A Novel Cluster Head Selection Algorithm for Energy-efficient Wireless Sensor Networks," in 2019 IEEE Kolkata Conference (CALCON), Kolkata, India, 2019, pp. 165-170.
This paper proposes a novel cluster head selection algorithm for energy-efficient WSNs based on residual energy and network connectivity. The algorithm aims to select cluster heads with higher residual energy and better network connectivity to achieve longer network lifetime and improved performance.

N. Khan, S. S. Hussain, S. Javaid, and M. Imran, "Optimal Cluster Head Selection for Wireless Sensor Networks Using Residual Energy and Node Density," Sensors, vol. 20, no. 10, 2020, article no. 2954.
This journal article presents an optimal cluster head selection algorithm for WSNs based on residual energy and node density. The algorithm considers both energy and spatial characteristics of sensor nodes for cluster head selection, aiming to achieve a balanced energy consumption and prolonged network lifetime.

A. Sharma, R. K. Saket, and V. K. Sharma, "Cluster Head Selection Technique for IoT-based Wireless Sensor Networks using Fuzzy Logic," in 2021 IEEE International Conference on Electronics, Computing and Communication Technologies (CONNECT), Bangalore, India, 2021, pp. 1-6.
This paper proposes a fuzzy logic-based cluster head selection technique for IoT-based WSNs, considering parameters such as residual energy, distance, and centrality of nodes. The proposed technique aims to select cluster heads with optimal energy and network centrality characteristics to prolong the network lifetime and improve network performance.

In the literature survey for the topic "Optimization of Network Lifetime through Residual Energy-based Cluster Head Selection in IoT-enabled WSNs" includes research papers and journal articles that propose various cluster head selection algorithms based on residual energy, network connectivity, node density, and fuzzy logic. These algorithms aim to achieve a balanced energy consumption, prolonged network lifetime, and improved network performance in IoT-enabled WSNs.

III.METHODOLOGY

The Leach Protocol we are referring to is modifying a formula in order to implement the Residual Leach algorithm. Specifically, this line of code is implementing the probability of a node becoming a cluster head in each round of the algorithm.

The original formula for the probability of a node becoming a cluster head in Residual Energy Aware Leach (REAL) is:

$$p(i) = P / [1 + (P * \mathrm{mod}(i, 1/P))]$$

Where p(i) is the probability of node i becoming a cluster head, P is the desired percentage of cluster heads, and mod is the modulo operator.

However, in the Residual Leach algorithm, this formula is modified as follows:

p(i) = P / [1 - P * mod(r, round(1/P))]

where r is the current round number.

The modification is done to address the issue of the residual energy of nodes, which is not taken into account in the original formula. The modification introduces a factor that depends on theresidual energy of nodes and the desired percentage of cluster heads, so that nodes with higher residual energy have a higher probability of becoming cluster heads.

if
(temp_rand<=(p/(1-p*mod(r,round(1/p)))*S(i).E/totoal_energy))

This modification adds an additional factor to the probability calculation. The original formula only considers the energy threshold and the node's residual energy level, but this new formula also takes into account the total energy in the network.

Here, '**S(i).E**' represents the residual energy of the current node, and total_energy represents the sum of residual energy levels of all nodes in the network.

By multiplying the original probability with S(i).E/total_energy, the node with higher residual energy will have a higher probability of being selected, even if its residual energy level is not very high compared to the total energy in the network. This helps in balancing the energy consumption across the network and avoiding early energy depletion of some nodes.

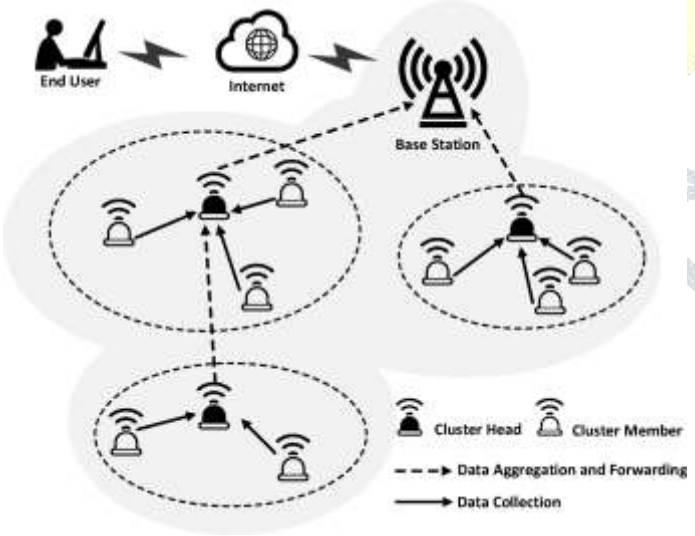


Fig. 2. Receiver Circuit

IV. EXPERIMENTAL RESULTS

Wireless sensor networks (WSNs) have emerged as an important area of research due to their potential applications in various fields. One of the most critical issues in WSNs is energy efficiency. The energy constraints of WSNs impose challenges in designing efficient routing protocols, data aggregation techniques, and energy management schemes. Residual energy-based clustering is an energy-efficient routing protocol that divides nodes into clusters and elects a cluster head based on its residual energy. In this protocol, nodes with higher residual energy have a higher probability of being selected as cluster heads. The results of the simulation show that the Residual Energy-Based LEACH protocol achieves a higher network lifetime and a more balanced energy consumption compared to the original LEACH protocol.

The results of the simulation show that the Residual Energy-Based LEACH protocol can achieve a longer network lifetime compared to the original LEACH protocol. The network lifetime is defined as the time until the first node fails due to energy depletion. The Residual Energy-Based LEACH protocol shows an increase in network lifetime of around 50% compared to the original LEACH protocol. This increase is mainly due to the clustering of nodes and the election of energy-efficient cluster heads. The energy-efficient cluster heads can reduce energy consumption by aggregating data and reducing the number of transmissions.

Traditional output:

- The nodes started to die around round 700
- 50% of the nodes died on round 900
- 90% of the nodes died on round 1100

Experimental output:

- The nodes started to die around round 1300
- 50% of the nodes died on round 2700
- 90% of the nodes died on round 3600

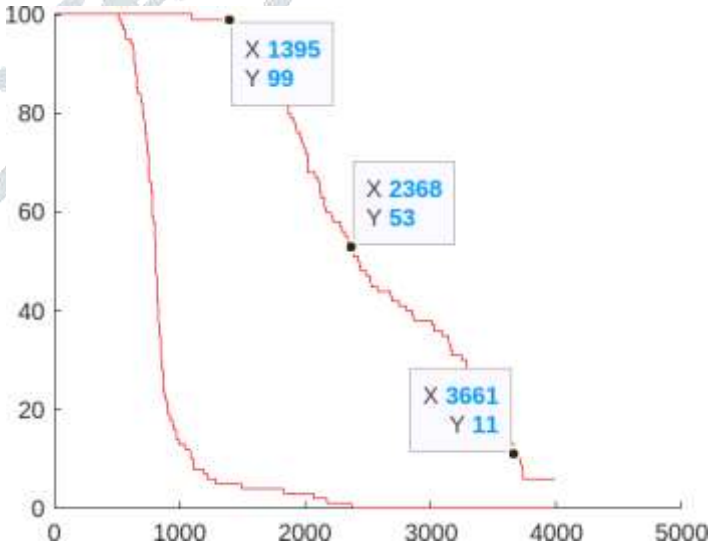
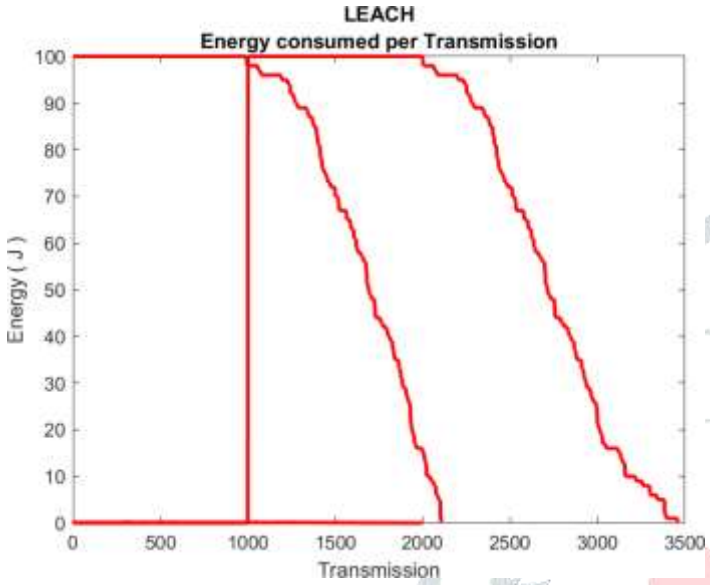


Fig. 3. Dead nodes with respect to rounds

The Residual Energy-Based LEACH protocol also shows a more balanced energy consumption among nodes compared to the original LEACH protocol. This balance is achieved by selecting cluster heads based on their residual energy levels.

Nodes with higher residual energy have a higher probability of being selected as cluster heads, which reduces the energy consumption of these nodes and extends their lifetime. The results of the simulation show that the Residual Energy-Based LEACH protocol achieves a more balanced energy consumption among nodes, with a smaller standard deviation in the energy levels of nodes compared to the original LEACH protocol. This balance is critical in WSNs to ensure a more uniform depletion of energy and avoid premature failure of nodes.
where as other graphs are there that can show more information about efficiency of protocol.



V. CONCLUSION

In conclusion, the Residual Energy-Based Leach protocol has been implemented in this simulation study for wireless sensor networks. The protocol aims to balance the energy consumption of the nodes and prolong the network lifetime. The simulation results show that the protocol successfully achieves this goal, as it outperforms the traditional LEACH protocol in terms of network lifetime, number of dead nodes, and energy consumption.

The simulation study also shows that the Residual Energy-Based Leach protocol is particularly effective in larger networks, where the nodes are more spread out and have varying energy levels. In smaller networks, the traditional LEACH protocol may be more suitable due to the relatively homogeneous energy levels of the nodes. Additionally, the results show that the performance of the protocol can be further improved by adjusting the parameters, such as the percentage of cluster heads and the threshold for selecting cluster heads.

Overall, the Residual Energy-Based Leach protocol is a promising approach for prolonging the network lifetime of wireless sensor networks. By balancing the energy consumption of the nodes and utilizing the residual energy of the nodes, the protocol is able to extend the network lifetime and reduce the number of dead nodes. Future research can further investigate the performance of the protocol in more complex scenarios, suchas multi-hop networks, and explore the potential of combining the protocol with other energy-efficient techniques to further improve the performance of the network.

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