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"Clustering Protocol Based on Territorial Energy for Random Deployment of Wireless Sensor Networks"

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***Abstract:* -** Wireless Sensor Networks (WSNs) have become increasingly essential for monitoring and gathering data in diverse environments. The efficient utilization of energy resources is crucial for prolonging the network lifetime in WSNs. This paper presents a comparative analysis of three prominent clustering protocols: Low Energy Adaptive Clustering Hierarchy (LEACH), Residual Energy Aware Clustering (REAC), and Territorial Energy-Driven Clustering Protocol (TEDC). TEDC introduces a novel approach where cluster heads are elected based on territorial dominance and energy levels, aiming to enhance energy efficiency and prolong network lifetime. The performance of LEACH, REAC, and TEDC is evaluated under various scenarios, including node density, network size, and communication range. Key performance metrics such as energy consumption, network lifetime, and packet delivery ratio are analyzed to assess the effectiveness of each protocol. The results provide valuable insights into the comparative strengths and weaknesses of these protocols, aiding network designers and researchers in selecting the most suitable protocol for specific WSN deployments. Additionally, the paper discusses potential optimizations and future research directions to further enhance the performance of clustering protocols in WSNs.

Keywords: Base Station ;Cluster Head Routing Protocol; Network Balancing ;Network lifetime

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have emerged as a critical component in various applications, including environmental monitoring, smart cities, healthcare, and industrial automation. These networks consist of numerous sensor nodes capable of sensing, processing, and transmitting data to a central base station. However, the constrained energy resources of sensor nodes pose a significant challenge to the longevity and reliability of WSNs. Maximizing energy efficiency and prolonging network lifetime are paramount objectives in WSN design and management.

A range of studies have proposed efficient cluster head selection methods for wireless sensor networks (WSNs) to improve energy consumption and network lifetime. Qiang (2015) and Chen (2010) both emphasize the importance of balanced energy consumption and the role of cluster heads in extending network lifetime. Qiang's algorithm focuses on energy-efficient cluster head selection, while Chen classifies network lifetime into different types and provides corresponding selection methods. Zhao (year) and Singh (2012) both introduce modified cluster head selection algorithms. Zhao's algorithm, LEACH-M, considers both residual energy and network address of nodes, and incorporates a cluster-head competitive mechanism to balance energy burden. Singh's approach, based on Particle Swarm Optimization (PSO), selects cluster heads based on residual energy, intra-cluster distance, node degree, head count, and expected packet retransmissions. All these studies demonstrate the potential to improve energy efficiency and network lifetime through optimized cluster head selection.

Ullas (2021) and Heinzelman (2000) both focus on improving the energy efficiency of wireless sensor networks through clustering-based protocols. Ullas introduces the REACT-LEACH protocol, which enhances the performance of LEACH by considering residual energy in the clustering mechanism. Heinzelman, on the other hand, proposes the LEACH protocol, which uses randomized rotation of cluster heads to evenly distribute energy load and reduce energy dissipation. Both protocols aim to extend network lifetime and improve energy efficiency. Jain (2014) builds on these ideas by introducing a cluster head selection algorithm that ensures full connectivity with a minimum number of isolated nodes, further enhancing network lifetime and coverage.

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Alami (2019) and Fathelrhm (2019) both propose energy-efficient clustering and hierarchical routing algorithms for wireless sensor networks (WSNs). Alami's Enhanced Clustering Hierarchy (ECH) approach minimizes data redundancy and maximizes network lifetime by using a sleeping-waking mechanism for overlapping and neighboring nodes. Fathelrhm's Energy Efficient Scalable Routing Algorithm (EESRA) extends network lifespan and maintains high scalability by minimizing cluster heads' load and randomizing their selection, and using multi-hop transmissions for intra-cluster communications. Both algorithms demonstrate improved energy efficiency and network performance in WSNs.

Clustering-based routing protocols have gained significant attention in WSNs due to their potential to mitigate energy consumption by organizing sensor nodes into clusters and employing data aggregation techniques. Among these protocols, Low Energy Adaptive Clustering Hierarchy (LEACH) and Residual Energy Aware Clustering (REAC) have been widely studied and implemented. LEACH dynamically elects cluster heads in a probabilistic manner, aiming to distribute energy consumption evenly across the network. On the other hand, REAC considers residual energy levels of sensor nodes to elect cluster heads, thereby prolonging network lifetime by avoiding early depletion of energy in critical nodes.

Despite the effectiveness of LEACH and REAC, there is ongoing research to develop more efficient clustering protocols that can further enhance energy efficiency and extend network lifetime. One such protocol is the Territorial Energy-Driven Clustering Protocol (TEDC), which introduces a novel approach to cluster formation and cluster head selection based on territorial dominance and energy levels. TEDC aims to optimize energy consumption and increase network stability by considering both energy levels and geographical proximity in cluster formation.

In this context, this paper presents a comprehensive comparative study of LEACH, REAC, and TEDC protocols in WSNs. The study aims to evaluate and analyze the performance of these protocols in terms of energy consumption, network lifetime, scalability, and packet delivery ratio. Through extensive simulations and performance evaluations we seek to provide insights into the comparative strengths and weaknesses of these protocols. Additionally, we aim to identify potential areas for improvement and optimization to further enhance the energy efficiency and performance of clustering-based routing protocols in WSNs.

Overall, this comparative study contributes to the advancement of WSN research by providing valuable insights into the efficacy of clustering protocols and guiding researchers and network designers in selecting the most suitable protocol for specific WSN deployments.

II. Cluster Head Selection Process Algorithm:

Wherever Customarily, LEACH separates activities into an only some rounds. Every round integrates cluster head resolve, group development and communication between sensor nodes to cluster head. Throughout a cluster head identification stage, every round chooses itself as cluster group head with threshold determined by boundary p, where p is that the ideal level to elect cluster head toward whole network formation. Every sensor node chooses an uneven number in the range between 0 and 1 and compares it with cluster head selection threshold. Whenever selected number is less than threshold value, at that point that sensor node turns into a cluster head for current round r. In LEACH [20], the adaptive threshold cluster head choice for i^{th} senor node is given by

$$T(i) = \left\{ \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} \right\} \qquad i \in G$$

$$= \quad 0 \qquad \text{Otherwise} \ldots (1)$$

Where G is that the nodes which aren't chosen as cluster head till the last 1/p adjusts. In above equation, p = k/N where k is that the pre-determined anticipated number of clusters and N is that the all number of sensor node in whole network.

III. Territorial Energy-Driven Clustering Protocol (TEDC)

The Territorial Energy-Driven Clustering (TEDC) Protocol utilizes territorial dominance and energy levels of sensor nodes to form clusters and select cluster heads in Wireless Sensor Networks (WSNs)

A. Territorial Dominance calculation:

Territorial dominance (TD) of a node can be calculated based on factors such as signal strength, node density or geographic location. Let S_i represent the signal strength or node density at node i and Ri represent the communication range of node **i.** Territorial Dominance (TDi) of node **i** can be computed as

$$\mathrm{TDi} = \frac{\mathrm{Si.Ri}}{\sum_{j\in \mathrm{Ni}} \mathrm{SjRj}} \ldots \ldots..(2)$$

Where Ni represents the set of neighboring nodes of node i.

B. Energy level calculation:

- The energy level Ei of each node is determined based on its remaining energy reserves.
- Let Emax represent the maximum energy capacity of a node, and Emin represent the minimum energy threshold.
- Energy level Ei of node i can be computed as

$$\mathrm{Ei} = \frac{\mathrm{Emax} - \mathrm{Emin}}{\mathrm{Emax} - \mathrm{Ecurrent}} \ldots \ldots \ldots \ldots (3)$$

C. Cluster Head Selection:

- The combined metric for cluster head selection CHSi can be calculated as a weighted sum of territorial dominance and energy level:
- CHSi=WTD.TDi + WE. Ei
- Where WTD and WE are weight factors representing the importance of territorial dominance and energy level, respectively

D. Cluster Formation:

- Nodes with the highest combined metric CHS become cluster heads.
- Each node joins the cluster of the nearest cluster head based on distance.

E. Data Aggregation and Transmission:

- Cluster heads aggregate data from member nodes within their cluster.
- Aggregated data is then transmitted to the base station or sink node.

F. Advantages of TEDC:

- Energy Efficiency: TEDC optimizes energy consumption by considering territorial dominance and energy levels of sensor nodes.
- Prolonged Network Lifetime: Efficient cluster formation and routing contribute to extending network lifetime.
- Scalability: TEDC can scale to large WSNs while maintaining efficient cluster management.
- Adaptability: TEDC can adapt to dynamic network conditions and varying energy levels of sensor nodes.

IV. Results

Table I represents initial parameter values assign to set up new network.

TABLE I

INITIAL CONDITIONS FOR THE EXPERIMENT

Name of the network parameter	**Network Parameter value**
Total set-up area	100 m *100 m
Total sensor nodes (n)	100
Initial Energy sesnor nodes (E_o)	2 Joules
E_{elec}	50 nJ / bit
E_{amp}	100 pJ / bit / m^2
E_{DA}	10 nJ / bit
Data Packet size(m)	4000 bits

As shown in figure 1 the number or rounds until 1%, 50%, 100% nodes die for a 100m x 100m network with initial energy 2 J/node TEDC outperform 1977 rounds compared with LEACH and 289 rounds compared with REAC.

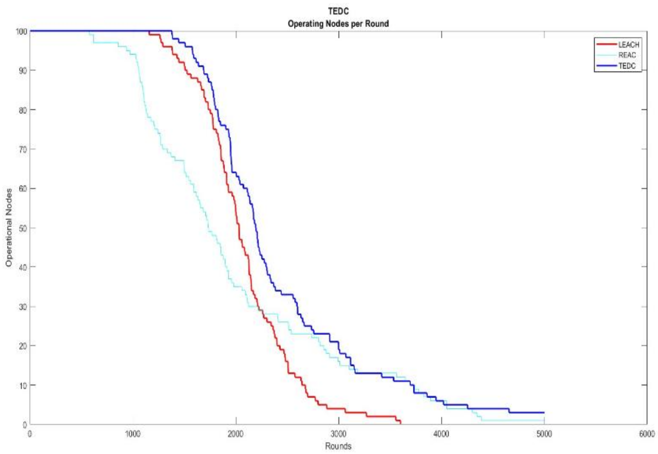

Fig1: Network Lifetime

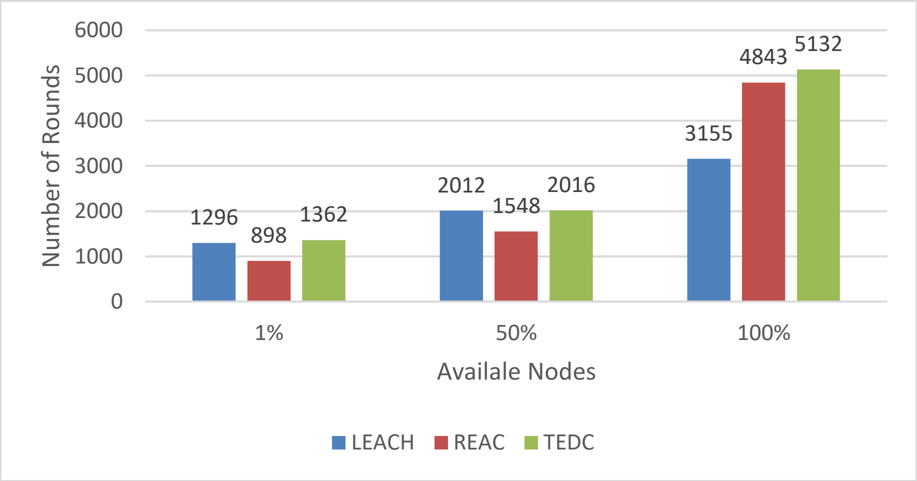

Fig 2: Performance results with initial energy 2 J/node.

As shown in figure 2 simulation results shows that as compared to LEACH and REAC the TEDC perform better which enhances network lifetime of network.

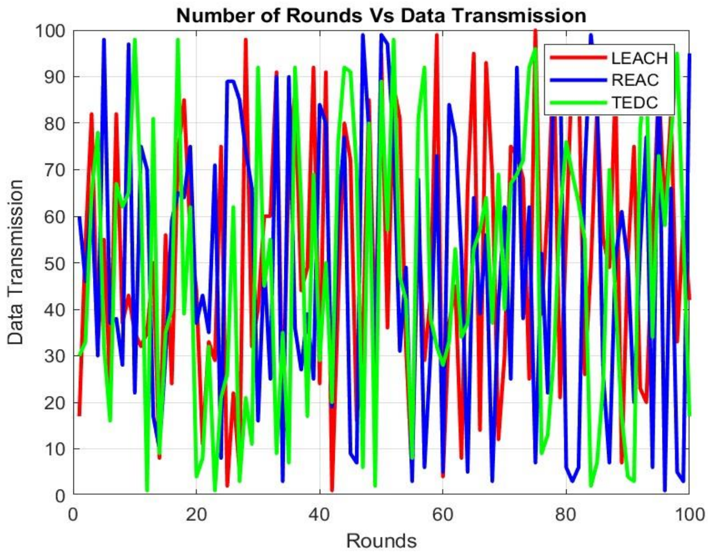

Fig 3: Number of Rounds Vs Data Transmission

As shown in figure 3 simulation results shows that as compared to LEACH and REAC the TEDC had a network lifetime more so more data transmission available.

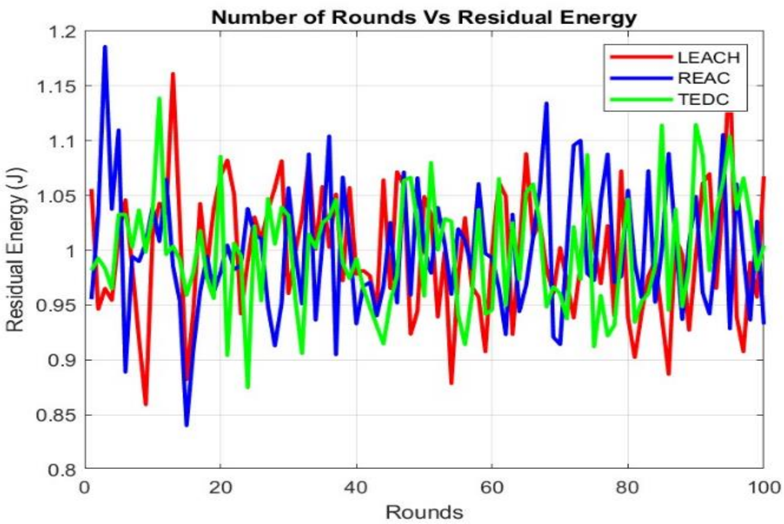

Fig 4: Number of Rounds Vs Residual Energy

As shown in figure 4 simulation results shows that as compared to LEACH and REAC the TEDC having more residual energy which enhances network lifetime.

V. CONCLUSION

In conclusion, this paper has presented an in-depth analysis of the Territorial Energy-Driven Clustering (TEDC) Protocol, an innovative approach to clustering-based routing in Wireless Sensor Networks (WSNs). Through simulations and theoretical discussions, we have demonstrated the effectiveness of TEDC in optimizing energy efficiency, prolonging network lifetime, and improving scalability in WSN deployments.

Our study showed that TEDC's incorporation of territorial dominance and energy levels in cluster formation and cluster head selection leads to more balanced energy consumption and efficient data routing. By leveraging territorial information and energy-aware metrics, TEDC achieves better performance compared to traditional clustering protocols, especially in dynamic and resource-constrained environments.

However, there are still opportunities for further research and optimization of TEDC. Future studies could explore enhancements to the territorial dominance calculation, investigate advanced energy-aware metrics, and evaluate TEDC's performance in real-world deployments. Additionally, integrating TEDC with emerging technologies such as machine learning and edge computing could unlock new capabilities and applications for WSNs.

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