

OPTIMIZATION OF EQDC PROTOCOL FOR IMPROVED ENERGY EFFICIENCY AND CLUSTER HEAD SELECTION IN WSN

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College : Dayananda Sagar College Of Engineering, Bengaluru
Branch : Department Of Information Science And Engineering
Guide(S) : Prof. Santosh Anand
Student(S) : Mr. Saiyam Goyal
Mr. Karan Devakatte
Mr. Mente Ganesh
Mr. Yuvraj G

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Introduction/Background:

Wireless Sensor Networks (WSNs) play a vital role in real-time monitoring and data collection across domains such as environmental monitoring, healthcare, industrial automation, smart cities, and military surveillance. These networks consist of small, low-power sensor nodes that transmit data to a central base station. However, their limited battery life and uneven node distribution often lead to coverage gaps, inefficient routing, and premature energy depletion.

To address these challenges, our project proposes an energy-efficient and stable WSN architecture using a dual approach:

1. Delaunay Triangulation to identify coverage holes and deploy mobile nodes for full area coverage.
2. Equi-Quadrant Division Clustering (EQDC) to organize nodes, select optimal Cluster Heads (CHs), and optimize routing via a Minimum Spanning Tree (MST).

This combined method enhances energy efficiency, prolongs network lifespan, and ensures consistent data transmission. With WSNs being integral to many critical applications, our solution offers a scalable and practical improvement in network performance and reliability.

Objectives:

- To enhance the energy efficiency and lifetime of Wireless Sensor Networks (WSNs) through intelligent clustering and routing.
- To identify and address coverage holes in WSNs using Delaunay Triangulation and strategically placed mobile nodes.
- To develop and implement the EQDC (Equi-Quadrant Division Clustering) algorithm for effective cluster head (CH) selection and load balancing.
- To ensure optimal data transmission paths by connecting CHs to the base station using Minimum Spanning Trees (MST).
- To compare the proposed method with existing protocols like LEACH and CLEACH, demonstrating improved performance in terms of node lifespan, energy consumption, and throughput.

Methodology:

This system enhances Wireless Sensor Networks (WSNs) by integrating Delaunay Triangulation for optimal node placement and the Equi-Quadrant Division Clustering (EQDC) protocol for efficient clustering and routing.

1. Network Setup:

- A 100×100 unit simulation area is modeled in MATLAB.
- 100 static sensor nodes are randomly deployed, with a Base Station (BS) at (50,120).
- All nodes start with equal energy and limited communication/sensing range.

2. Delaunay Triangulation & Mobile Node Placement:

- Delaunay Triangulation is applied to the node layout to form nonoverlapping triangles.

- Longest triangle edges indicate sparse regions; mobile nodes are placed at their midpoints to fill coverage gaps.
 - The network is re-triangulated after node placement to reflect updated topology.
3. EQDC – Clustering & Cluster Head (CH) Selection:
- The area is divided into four quadrants.
 - Initial CHs are selected based on proximity to the BS; re-elected based on residual energy and distance to ensure energy efficiency.
 - Sensor nodes send data to their respective CHs for aggregation and forwarding.
4. Routing via Minimum Spanning Tree (MST):
- An MST connects CHs, reducing inter-cluster communication cost and overall energy usage by avoiding direct CH-to-BS transmissions.
5. Performance Evaluation:
- Metrics analyzed:
- Alive nodes over time
 - Packets sent to BS
 - Energy consumption
 - CHs per round
 - Node failures

Results & Conclusions:

The proposed EQDC-based WSN architecture was evaluated using MATLAB simulations over 2000 rounds with 100 static sensor nodes and 10 mobile nodes. The simulation results were compared against standard LEACH and C-LEACH protocols using key performance indicators like node lifetime, energy consumption, cluster head stability, and data throughput.

Key findings include:

- **Extended Network Lifetime:** EQDC maintained more active nodes beyond 1800 rounds, whereas LEACH and C-LEACH networks mostly failed by 900–1400 rounds.

- **Efficient Energy Utilization:** EQDC showed a more gradual decline in residual energy, while LEACH depleted energy rapidly by 800–1000 rounds.
- **Stable Cluster Head Formation:** EQDC maintained a steady number of CHs, while LEACH and C-LEACH displayed sharp fluctuations and instability.
- **Improved Throughput:** EQDC consistently transmitted more packets to the base station, ensuring better data delivery.
- **Lower Node Failures:** The count of dead nodes rose more slowly in EQDC compared to LEACH and C-LEACH.

These results clearly demonstrate that the EQDC protocol, when combined with Delaunay triangulation-based mobile node placement, offers significant improvements in energy efficiency, coverage, and network stability for WSNs. It is especially beneficial for large-scale, energy-constrained applications in fields like environmental monitoring and smart cities.

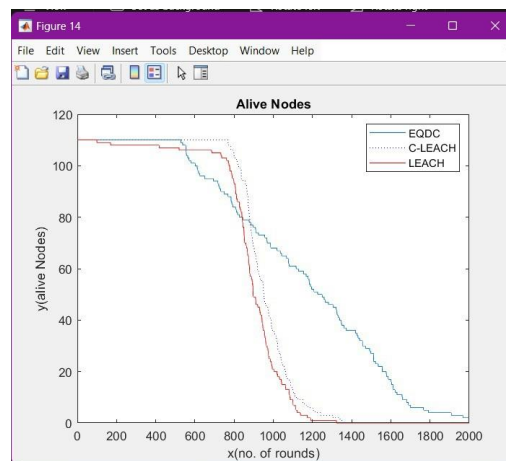


Figure 1: No. of Alive Nodes

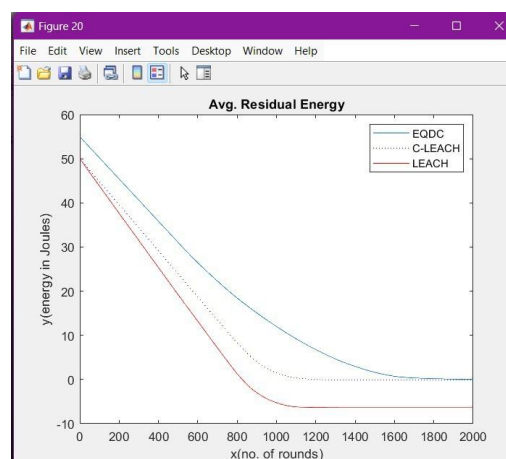


Figure 2: Avg. Residual Energy

Project Outcome & Industry Relevance :

The project successfully demonstrates a scalable and energy-efficient solution for improving the performance of Wireless Sensor Networks (WSNs) through intelligent clustering and optimized routing. By integrating Delaunay triangulation and the EQDC protocol, the system ensures better coverage, load balancing, and longer network lifespan.

This approach directly contributes to the field of WSN by addressing key limitations in traditional protocols like LEACH, especially in terms of energy depletion, coverage holes, and unstable cluster formation.

In real-world applications, this system can be deployed in:

- Environmental monitoring (forests, oceans, agricultural fields)
- Smart cities (traffic management, pollution monitoring)
- Industrial IoT (machine health and infrastructure surveillance)
- Military surveillance and disaster response

Its ability to self-heal coverage holes and adapt to dynamic environments makes it highly relevant for modern, large-scale, and mission-critical deployments where maintenance access is limited and efficiency is essential.

Working Model vs. Simulation/Study:

This project was primarily a simulation-based study conducted using MATLAB. The focus was on evaluating the performance of the proposed EQDC protocol and Delaunay triangulation-based node placement in a simulated Wireless Sensor Network (WSN) environment.

No physical working model was developed, but the simulation closely mimics real-world deployment scenarios by modeling node distribution, energy usage, communication paths, and routing behavior. The results demonstrate strong theoretical viability and lay the foundation for future implementation in hardware-based WSN systems.

Project Outcomes and Learnings:

Project Outcomes:

- Successfully developed and simulated an energy-efficient WSN protocol (EQDC).
- Improved network lifetime, coverage, and data throughput compared to LEACH and CLEACH.
- Demonstrated the effectiveness of Delaunay triangulation in detecting and patching coverage holes.
- Achieved balanced cluster head selection and efficient data routing using minimum spanning trees.
- Provided a scalable model suitable for real-world applications like smart cities, healthcare, and environmental monitoring.

Learnings:

- Gained deep insights into WSN architecture, challenges, and optimization strategies.
- Learned how to simulate real-world network behavior using MATLAB.
- Understood the importance of efficient resource management in low-power networks.
- Developed skills in algorithm design, data analysis, and performance evaluation.
- Recognized how small changes in topology and routing can greatly impact the overall network performance and energy efficiency.

Future Scope :

The future scope of this project includes:

1. Implement dynamic quadrant resizing based on real-time node density for better load balancing.
2. Use machine learning (e.g., reinforcement learning, decision trees) for smarter CH selection.

3. Analyze node energy, location, and performance history to enhance clustering decisions.
4. Apply predictive models like Kalman filters to enable mobility-aware clustering.
5. Adjust cluster assignments proactively by anticipating node movements.
6. Introduce multi-hop intra-cluster communication to reduce energy usage for distant nodes.
7. Deploy fault-tolerant mechanisms like backup CHs and decentralized fault detection.
8. Extend the protocol for heterogeneous WSNs handling different sensor types and data priorities.
9. Integrate with cloud and edge computing for real-time data analytics and scalable systems.
10. Apply the protocol in domains like underwater sensing, industrial monitoring, healthcare, and disaster management.
11. Support hardware miniaturization and energy harvesting for long-term autonomous operation