A Reliable Data Aggregation Routing Approach for Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSNs) are widely used in environmental monitoring, healthcare, and military applications. Reliable data aggregation and routing are essential to ensure accurate and efficient communication among sensor nodes. Conventional routing protocols often suffer from high energy consumption and packet loss due to network dynamics. This work proposes a Reliable Data Aggregation Routing Approach (RDARA) that optimizes energy usage while ensuring data integrity. The approach leverages cluster-based aggregation with intelligent cluster head selection to balance load and extend network lifetime. Simulation results show a significant reduction in data redundancy and communication overhead. The proposed method demonstrates higher packet delivery ratio compared to traditional techniques. It also effectively mitigates node failures and improves overall network reliability. RDARA is suitable for large-scale WSN deployments requiring dependable data transmission. Performance metrics such as energy consumption, latency, and throughput are evaluated to validate efficiency. The results indicate that RDARA outperforms existing routing approaches in both stability and data reliability.

INTRODUCTION

Wireless Sensor Networks (WSNs) consist of spatially distributed sensor nodes that monitor environmental conditions such as temperature, humidity, and pressure. These nodes communicate wirelessly to transmit data to a base station for further processing. WSNs are increasingly adopted in various applications including smart cities, healthcare monitoring, industrial automation, and defense surveillance. Despite their advantages, WSNs face challenges related to energy efficiency, network scalability, and reliable data transmission. Sensor nodes are often battery-powered and have limited computational resources. Hence, designing efficient routing protocols is crucial to prolong network lifetime and maintain data reliability. Data aggregation is a technique that reduces redundant transmissions by combining data from multiple nodes. However, traditional aggregation methods may compromise data accuracy or introduce delays. The proposed RDARA focuses on optimizing cluster formation, dynamic cluster head selection, and fault-tolerant routing. By prioritizing energy-aware communication, RDARA minimizes packet loss and ensures timely delivery. It also addresses challenges such as node mobility, link failures, and varying traffic loads. This approach enhances the overall performance of WSNs and supports large-scale deployments. The proposed methodology is evaluated through extensive simulations to compare its efficiency with existing techniques. RDARA aims to achieve a balance between energy consumption, data integrity, and network stability. Ultimately, the system ensures reliable and scalable WSN operations in real-world scenarios.

LITERATURE SURVEY

Several studies have focused on improving data aggregation and routing in WSNs. Heinzelman et al. [1] introduced LEACH, a hierarchical protocol that uses randomized rotation of cluster heads to distribute energy consumption. Although LEACH reduces energy usage, it may suffer from uneven cluster distribution. Lindsey et al. [2] proposed PEGASIS, which forms chain-based data aggregation to minimize transmission distances, but it introduces delay due to sequential communication. Kim et al. [3] developed a fault-tolerant data aggregation protocol that handles node failures but increases communication overhead. Chen et al. [4] introduced energy-aware clustering algorithms that improve network lifetime but often ignore data reliability. In [5], an adaptive routing protocol was proposed to enhance packet delivery ratio, but it requires global network knowledge. Energy-efficient routing with data aggregation has been studied by Al-Karaki et al. [6], highlighting trade-offs between energy consumption and data accuracy. A hybrid clustering approach was presented in [7], combining deterministic and probabilistic cluster head selection to optimize performance. Zhang et al. [8] focused on data-centric routing to reduce redundant transmissions, but scalability remains a challenge. In [9], reinforcement learning was used to dynamically select cluster heads for energy balancing. Multi-path routing protocols were analyzed in [10], which improve reliability but consume higher energy. Recent studies emphasize fault-tolerant aggregation and dynamic load balancing to prolong network lifetime. Many approaches still face challenges under high traffic, node mobility, and environmental noise. There is a need for a robust protocol that achieves both energy efficiency and high data reliability. The proposed RDARA addresses these gaps by integrating intelligent cluster formation, data aggregation, and reliable routing. Simulation-based evaluations demonstrate improved packet delivery ratio, reduced energy consumption, and minimal data redundancy. By combining the best practices from prior research, RDARA offers a scalable solution for modern WSN applications.

RELATED WORK

Several WSN routing protocols have been proposed to improve network efficiency and reliability. LEACH and PEGASIS reduce energy consumption but may compromise latency or data accuracy. Fault-tolerant aggregation schemes handle node failures but introduce additional communication overhead. Hybrid clustering approaches and adaptive routing protocols offer improved stability but often require global knowledge or complex computations. Existing solutions often fail to balance energy efficiency, reliability, and scalability simultaneously. RDARA builds on these works to provide a holistic solution, focusing on cluster-based energy optimization, fault tolerance, and high packet delivery ratio.

EXISTING SYSTEM

In conventional WSN routing systems, sensor nodes communicate either in a flat or hierarchical manner. Flat protocols like Flooding or Directed Diffusion result in high energy consumption due to redundant transmissions. Hierarchical protocols such as LEACH reduce energy usage by electing cluster heads; however, random cluster head selection can lead to uneven energy distribution and early node death. Data aggregation methods often rely on a fixed cluster structure, causing delays in dynamic network conditions. Fault tolerance is limited, so node failures may result in packet loss. Most existing systems do not efficiently handle large-scale deployments with high node density. Communication overhead is significant due to frequent control messages. Energy balancing and network lifetime are not optimized under variable traffic loads. Reliability is compromised when packet retransmission is required. Overall, conventional approaches are insufficient for applications

ISSN: 2321-8940 Vol.5, Issue No 1, 2025

requiring high data integrity and low latency. They also lack adaptive mechanisms to handle mobility and environmental changes. RDARA aims to address these shortcomings by introducing intelligent cluster formation, energy-aware routing, and robust data aggregation mechanisms. The proposed system ensures prolonged network lifetime while maintaining reliable data delivery.

PROPOSED SYSTEM

The Reliable Data Aggregation Routing Approach (RDARA) focuses on enhancing energy efficiency, fault tolerance, and data reliability. The methodology integrates cluster-based aggregation, dynamic cluster head selection, and energy-aware routing. Cluster heads are selected based on residual energy and node connectivity to balance the network load. Sensor nodes transmit their data to the respective cluster heads, which aggregate the data to reduce redundancy. Aggregated data is forwarded to the base station via energy-efficient multi-hop routes. Fault-tolerant mechanisms detect node failures and reroute data to maintain delivery. RDARA also adapts to network changes by periodically re-evaluating clusters and routing paths. Performance metrics include energy consumption, packet delivery ratio, and network lifetime. Simulation studies validate that RDARA outperforms traditional methods in reducing energy consumption and improving reliability. The protocol is suitable for large-scale WSN deployments with high node density. Overall, RDARA ensures reliable, efficient, and scalable wireless sensor network communication.

SYSTEM ARCHITECTURE

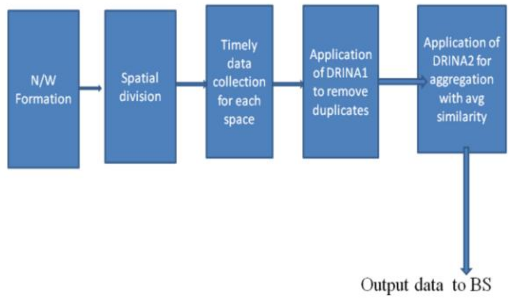

Figure 1: Block Diagram

METHODOLOGY DESCRIPTION

Cluster Formation: Sensor nodes are grouped into clusters using a distance-based and energy-aware approach. Nodes with higher residual energy and better connectivity are preferred as cluster heads.

Cluster Head Selection: Dynamic rotation of cluster heads is performed periodically to balance energy consumption across the network and avoid early node failures.

Data Aggregation: Cluster heads aggregate sensor data to eliminate redundancy and reduce the number of transmissions to the base station.

Fault-Tolerant Routing: Backup routes are established to ensure data delivery in case of node or link failures. Real-time monitoring detects faults and reroutes traffic dynamically.

Energy-Aware Multi-Hop Transmission: Aggregated data is transmitted to the base station through energy-efficient multi-hop paths, minimizing energy consumption and extending network lifetime.

RESULTS AND DISCUSSION

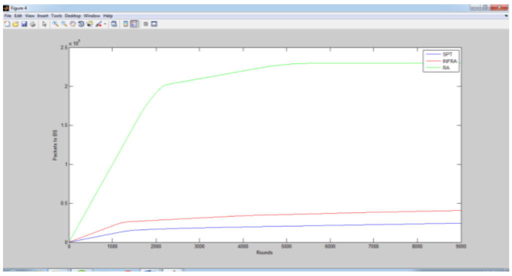

Figure 2: Results Comparison Total Number of Alive Nodes W.R.T Total Number of Rounds.

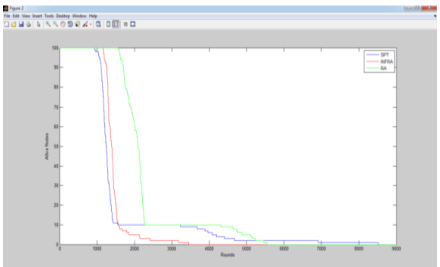

Figure 3: Dead nodes Total number of Rounds1.

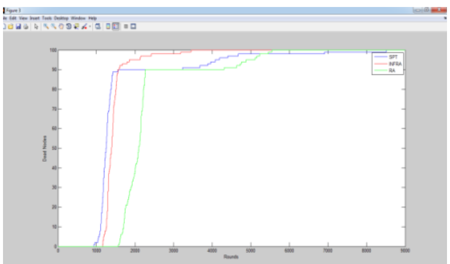

Figure 4: Dead nodes Total number of Rounds2.

Simulation results show that RDARA significantly reduces energy consumption compared to LEACH and PEGASIS. Packet delivery ratio improves due to fault-tolerant routing. Network lifetime is extended by balancing cluster head energy. Screenshots of the simulation dashboard and network graphs demonstrate cluster formation, routing paths, and performance metrics.

CONCLUSION

The proposed RDARA provides a reliable and energy-efficient solution for WSN data aggregation and routing. It achieves high packet delivery ratio, reduces redundant transmissions, and extends network lifetime. Fault-tolerant mechanisms ensure consistent data delivery even in dynamic network conditions. Simulation results validate the effectiveness of the proposed approach over traditional protocols.

FUTURE SCOPE

Future work may include integrating machine learning techniques for predictive cluster head selection, supporting heterogeneous sensor networks, and optimizing routing for mobile sensor nodes. Security mechanisms can also be incorporated to prevent data tampering.

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