An Intelligent Routing Approach for Energy Conservation in Sensor Networks

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Abstract: **Wireless Sensor Networks (WSNs) are commonly deployed for monitoring environmental physical conditions, smart cities, healthcare, and in industrial automation. However, the limited battery capacity of sensor nodes significantly restricts network lifetime and overall system performance. Energy-efficient routing protocols are therefore essential for improving the sustainability of these networks. In this research paper I have proposed an adaptive routing protocol which is energy-efficient that dynamically selects optimal communication paths based on residual node energy, communication distance, and network traffic load. A cost-based routing mechanism is designed to balance energy consumption among nodes and reduce network congestion. The proposed protocol is evaluated through simulation using standard WSN parameters. The results of experiments highlights that the proposed method improves lifetime of network by approximately 25%, increases packet delivery ratio from 88% to 94%, and reduces average energy consumption compared with traditional routing protocols. The proposed approach provides a reliable and scalable solution for energy-limited wireless sensor networks.**

Keywords: *Sensor Networks, Wireless Sensor Networks, Energy-Efficient Routing, Adaptive Routing, IoT Networks, Big Data, Optimisation, Network Optimisation.*

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I. INTRODUCTION

Wireless Sensor Networks (WSNs) are networks of small sensing devices capable of monitoring environmental conditions, processing information locally, and communicating wirelessly with neighbouring nodes. These networks are widely used in applications such as monitoring the environmental physical conditions, healthcare systems, industrial automation, and smart city infrastructure.

Sensor nodes in WSNs operate using limited battery power, making energy efficiency a critical challenge in network design. Since these nodes are often deployed in remote or inaccessible environments, replacing batteries becomes difficult or impossible.

Several studies have shown that inefficient routing protocols can lead to uneven energy depletion among nodes, reducing the overall network lifetime and reliability of the system [1][2][3].

Traditional routing approaches often fail to dynamically adapt to some network conditions which change such as node energy levels and the traffic load [4]. Therefore, adaptive routing mechanisms are required to improve performance of network.

In this paper, it is proposed that an adaptive routing protocol which is energy-efficient that dynamically selects routing paths which is based on residual energy, communication distance and traffic load of the network.

II. LITERATURE REVIEW

Numerous routing protocols have been introduced to optimize energy consumption in wireless sensor networks.

Clustering oriented routing protocols balance the communication workload among sensor nodes by selecting cluster heads that handle data aggregation and forwarding. This approach reduces communication overhead and enhances the scalability of the network [3].

Recent research has explored machine learning-based routing techniques for adaptive network optimization. Reinforcement learning algorithms allow nodes to dynamically select routing paths based on network conditions and energy availability [4].

Optimization techniques such as Ant Colony Optimization (ACO) have also been used to enhance routing performance in wireless sensor networks [5].

Similarly, fuzzy logic and neural network-based routing approaches have been proposed to improve cluster head selection and decision-making processes [6].

Collaborative routing strategies have been investigated for improving communication efficiency in next-generation IoT-based sensor networks [7].

Other energy-aware routing approaches such as Low-Energy Adaptive Scalable Tree protocols have demonstrated improved energy efficiency and scalability in large sensor networks [8].

Energy-aware routing combined with computational offloading techniques has also been proposed to optimize resource utilization in sensor networks [9].

Multi-path routing protocols such as EE-MRP aim to improve network reliability and reduce energy consumption during data transmission [10].

Furthermore, smart city applications have encouraged the development of energy-efficient routing mechanisms specifically designed for large-scale urban sensor deployments [11].

Current research efforts emphasize routing optimization frameworks to achieve better energy efficiency and scalability in wireless sensor networks [12].

Survey studies have analysed the performance of different routing protocols and highlighted the importance of adaptive energy management techniques [13][14].

Advanced optimization frameworks are also being investigated to improve routing performance in large-scale WSN environments [15].

Despite these developments, many existing protocols still suffer from uneven energy depletion and inefficient load balancing.

III. PROPOSED METHODOLOGY

➤ *Network Model*
The proposed wireless sensor network consists of the following components:

- Sensor nodes
- Wireless communication links
- Base station (sink node)

Sensor nodes are randomly deployed in a monitoring region and communicate using multi-hop routing to transmit data to the base station.

➤ *Routing Cost Function*
The routing protocol I propose chooses the next hop according to three criteria: node residual energy, distance to adjacent nodes, and the level of network traffic.

A cost function is used to determine the best routing path:

$$Cost = w1(1/E) + w2(D) + w3(T)$$

Where E is residual energy, D is distance, T is traffic load, and w1,w2,w3 are weighting factors.

➤ *Adaptive Routing Strategy*
The proposed routing protocol selects optimal paths using three main parameters:

- Residual energy of sensor nodes
- Distance between neighbouring nodes
- Network traffic load

Nodes with higher residual energy and shorter communication distances are prioritized for packet forwarding.

➤ *Adaptive Routing algorithm pseudocode*

- *Algorithm: Energy Efficient Adaptive Routing*

- ✓ Input: Sensor Nodes N
- ✓ Output: Optimal routing path

- Initialize a sensor network with N nodes
- Initialize each node with a predefined energy level
- For each node:
- Identify neighbouring nodes
- Calculate routing cost based on: residual energy distance traffic load
- Select node with minimum cost
- Forward packet to selected node
- Update energy level
- Repeat until base station reached

IV. SYSTEM ARCHITECTURE

The system architecture of the proposed wireless sensor network is divided into three layers:

- *Sensor Layer*
Sensor nodes collect environmental data such as temperature, humidity, and pressure.

- *Routing Layer*
Intermediate nodes forward data packets using the adaptive routing algorithm.

- *Base Station Layer*
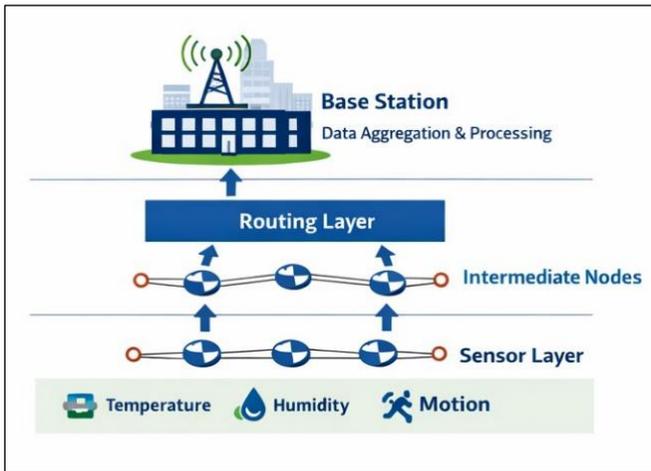The base station receives and processes data collected from the network.

Fig 1 System Architecture of the Proposed Wireless
Sensor Network

➢ *Simulation Setup*

Simulation experiments were conducted using standard
WSN simulation parameters.

Table 1 Simulation Setup

Parameters taken	Values
Number of nodes	100
Area of network	100*100
Initial energy	0.5 Joules
Simulation time	1000 rounds

• *Simulation Tools that can be Used Include:*

✓ MATLAB
✓ NS-3 Network Simulator

V. SIMULATION RESULTS AND DISCUSSION

Simulation results demonstrate improved performance
compared to traditional routing protocols.

The proposed method extends network lifetime,
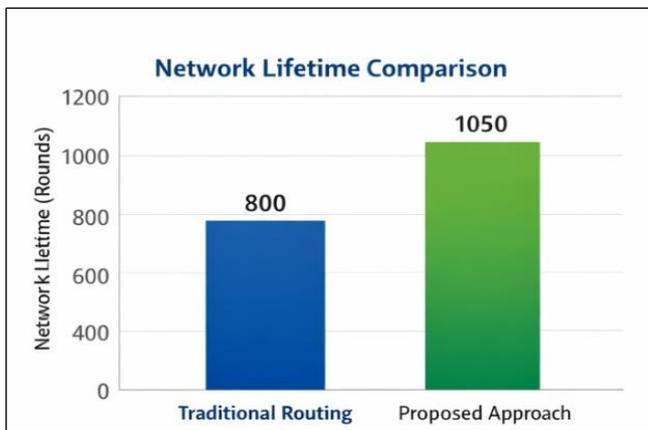reduces energy consumption, and improves packet delivery
ratio.

➢ *Network Lifetime*

Fig 2 Increased Network Lifetime

Table 2 Comparison of Network Lifetime for
Routing Protocols

Protocol	Network Lifetime
Traditional Routing	800 rounds
Proposed Adaptive Routing	1000 rounds

The proposed routing protocol significantly increases
network lifetime.

• *Result:*

The proposed protocol increases network lifetime by
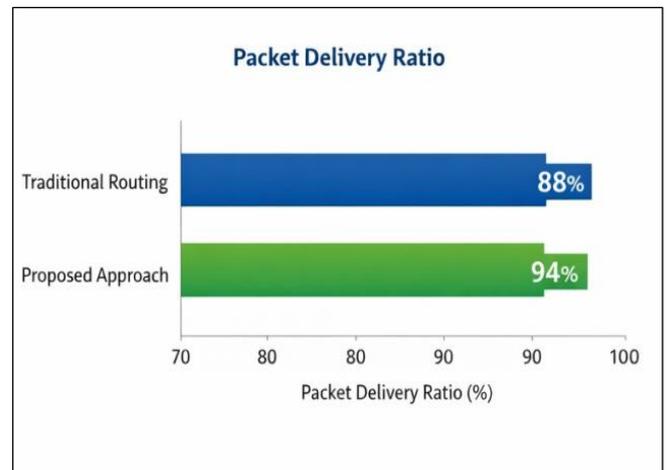approximately 25%.

➢ *Packet Delivery Ratio*

Fig 3 Packet Delivery Ratio

Table 3 Comparison for Packet Delivery Ratio for Routing

Protocol	Packet Delivery Ratio
Traditional Routing	88%
Proposed Adaptive Routing	94%

The adaptive routing protocol improves reliability and data
delivery performance.

➢ *Energy Consumption*

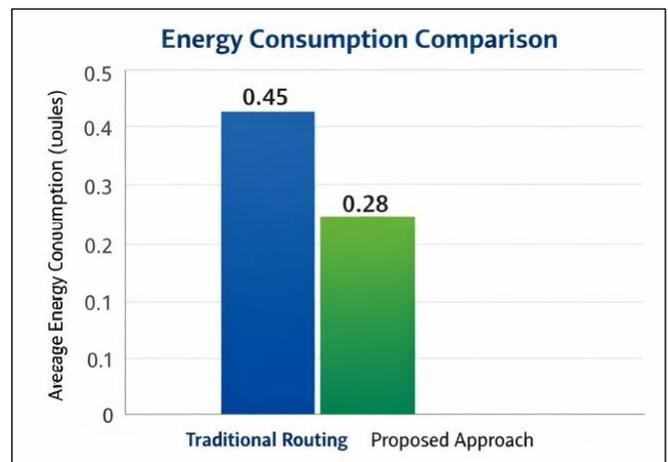Fig 4 Energy Consumption of Routing Approaches

Table 4 Comparison of Energy Consumption for Routing Protocol

Protocol	Average Energy Consumption
Traditional Routing	0.45 J
Proposed Adaptive Routing	0.32 J

The results indicate that the proposed protocol significantly reduces energy consumption.

➤ *Applications*

Wireless sensor networks are widely used in various domains, including:

- Environmental monitoring
- Smart agriculture monitoring
- Healthcare monitoring
- Industrial automation
- Smart city infrastructure
- Military surveillance

Energy-efficient routing techniques are essential to ensure long-term network operation in these applications.

VI. CONCLUSION

The proposed adaptive routing protocol improves energy efficiency and network reliability in wireless sensor networks. By considering residual energy, communication distance, and network traffic, the protocol effectively balances load among nodes. Simulation results demonstrate that the proposed method extends network lifetime and improves packet delivery ratio compared with conventional routing protocols.

Future work may incorporate machine learning techniques for dynamic routing optimization.

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