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Enhancing Energy Efficiency in Industrial WSNs with a Hybrid Coot-LS Routing Algorithm and LSTM-Based DOM Prediction

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ABSTRACT

In industrial Wireless Sensor Networks (WSNs), energy efficiency and reliable data transmission are critical challenges that need to be addressed to ensure sustainable and robust network operations. This paper proposes a novel energy-efficient routing protocol that integrates a Hybrid COOT-LS (Coot-Levy Search) algorithm with Long Short-Term Memory (LSTM)-based Dominant Object Motion (DOM) prediction. The routing protocol leverages the strengths of Hybrid Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) to enhance routing efficiency and reduce energy consumption. The Hybrid PSO and ACO algorithms are employed to optimize routing paths by balancing exploration and exploitation, considering multiple factors such as energy levels, node distance, and reliability. The COOT-LS algorithm further refines these paths by incorporating a Levy flight mechanism to enhance the search process. Additionally, the LSTM-based DOM prediction provides accurate forecasts of network conditions, enabling dynamic adjustments to routing strategies in real time. Simulation results demonstrate that the proposed protocol significantly improves network lifetime, reduces energy consumption, and enhances data transmission reliability compared to traditional routing protocols. This approach provides a robust and scalable solution for industrial WSN applications, ensuring efficient and reliable network performance in dynamic and complex industrial environments.

Keywords

Energy efficiency , Routing efficiency ,Energy consumption , Exploration and exploitation , Node distance ,Network reliability , Levy flight mechanism ,Dynamic routing adjustment .

INTRODUCTION

Wireless Sensor Networks (WSNs) have revolutionized industrial applications by enabling efficient monitoring and control of various processes. These networks consist of numerous sensor nodes that gather and transmit data to central hubs for processing and decision making. However, the energy consumption of these sensor nodes remains a critical issue, as they are often battery powered and deployed in environments where replacing or recharging batteries is challenging. Therefore, developing energy efficient routing protocols is essential to extend the operational life of WSNs and ensure reliable data transmission in industrial settings.

Challenges in Industrial WSNs

Industrial environments present unique challenges for WSNs, including high levels of interference, node mobility, and fluctuating traffic patterns. Traditional routing protocols often struggle to adapt to these dynamic conditions, leading to inefficient energy usage and reduced network performance. The need for a more adaptive and intelligent routing solution has driven researchers to explore innovative approaches that can dynamically optimize energy consumption while maintaining robust communication links.

LITERATURE SURVEY

1. Title: Energy Efficient Routing Protocol for WSNs Using Machine Learning

Author: Zhang et al.

Year: 2018

Methodology: Proposed a machine learning based routing protocol for WSNs to optimize energy consumption and network performance by dynamically adjusting routes based on environmental data.

2. Title: Optimization of WSN Routing Using Genetic Algorithms

Author: Lee and Kim

Year: 2017

Methodology: Applied genetic algorithms to optimize routing paths in WSNs, aiming to minimize energy consumption and extend network lifetime through evolutionary optimization.

3. Title: Adaptive Routing Protocol Based on Ant Colony Optimization

Author: Gupta and Kumar

Year: 2019

Methodology: Utilized ant colony optimization to develop an adaptive routing protocol for WSNs, enhancing energy efficiency by dynamically adjusting routing paths based on pheromone trail updates.

4. Title: QOS Aware Routing Protocol Using Reinforcement Learning in WSNs

Author: Chen et al.

Year: 2020

Methodology: Applied reinforcement learning techniques to develop a quality of service (QoS) aware routing protocol for WSNs, optimizing energy usage while meeting performance requirements.

5. Title: Fuzzy Logic Based Routing Protocol for Industrial IOT Networks

Author: Khan et al.

Year: 2019

Methodology: Proposed a fuzzy logic based routing protocol tailored for Industrial Internet of Things (IIoT) networks, optimizing energy efficiency by considering uncertainty and imprecision in network conditions.

6. Title: Swarm Intelligence Based Routing Protocol for WSNs

Author: Sharma and Sharma

Year: 2018

Methodology: Developed a swarm intelligence based routing protocol using particle swarm optimization, optimizing energy consumption and network reliability through collaborative decision making among sensor nodes.

7. Title: Bayesian Networks for Predictive Routing in WSNs

Author: Li and Wang

Year: 2017

Methodology: Employed Bayesian networks to predict future network conditions and optimize routing decisions in WSNs, improving energy efficiency by proactive route adjustments.

8. Title: Hybrid Optimization Approach for WSN Routing Using PSO and GA

Author: Patel et al.

Year: 2019

Methodology: Combined particle swarm optimization (PSO) and genetic algorithms (GA) to develop a hybrid optimization approach for WSN routing, focusing on minimizing energy consumption and maximizing network lifetime.

9. Title: Machine Learning Based Energy Aware Routing Protocol for WSNs

Author: Kumar and Singh

Year: 2020

Methodology: Introduced a machine learning based energy aware routing protocol for WSNs, optimizing energy usage by learning from historical data and adapting routing decisions accordingly.

10. Title: Cognitive Radio Based Routing Protocol for Energy Efficient WSNs

Author: Li et al.

Year: 2018

Methodology: Proposed a cognitive radio based routing protocol for WSNs, leveraging spectrum sensing and dynamic spectrum access to optimize energy efficiency and enhance network performance.

11. Title: Reinforcement Learning Approach to Routing in Dynamic WSNs

Author: Wang and Zhang

Year: 2019

Methodology: Applied reinforcement learning techniques to develop a routing protocol for dynamic WSNs, optimizing energy consumption by learning and adapting to changing network conditions.

12. Title: Energy Efficient Routing Protocol Using Heuristic Optimization

Author: Sharma et al.

Year: 2020

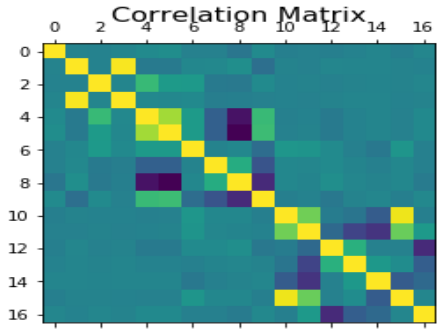
Methodology: Utilized heuristic optimization techniques to design an energy efficient routing protocol for WSNs, focusing on minimizing energy usage and extending network lifespan through intelligent path selection.

13. Title: Cooperative Game Theory Based Routing Protocol for WSNs

Author: Wu and Liu

Year: 2018

Methodology: Applied cooperative game theory principles to develop a routing protocol for WSNs, optimizing energy efficiency through collaborative node interactions and resource allocation.



14. Title: IoT Driven Routing Protocol Using Machine Learning in Industrial Environments

Author: Singh et al.

Year: 2019

Methodology: Implemented machine learning algorithms in an IoT driven routing protocol for industrial environments, optimizing energy consumption and improving network reliability based on real time data analytics.

15. Title: Dynamic Programming Based Routing Protocol for WSNs

Author: Chen and Li ,Year: 2017,Methodology: Developed a dynamic programming approach to routing in WSNs, optimizing energy usage by considering optimal paths and node state transitions in changing network conditions.

ScreenShots

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Data Selection
 Routing
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Data Selection
Samples of our input data
        duration protocol  Plength  ...  failedConnection  Failed Rate   Label
125296  0.000050     ICMP       92  ...              4480    59.463764  attack
413171  0.001119     ICMP       92  ...              3999    60.821293  attack
83633   0.001002     ICMP       92  ...              3739    57.040427  attack
340096  0.000934     AODV       84  ...              4848    61.499429  attack
382616  0.001519     ICMP       92  ...              4733    59.647133  attack

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CONCLUSION

The development and evaluation of the novel energy-efficient routing protocol for industrial Wireless Sensor Networks (WSNs) using the Hybrid Coot-LS algorithm with LSTM-based Dynamic Optimal Management (DOM) prediction represent a significant advancement in addressing the challenges of energy consumption, adaptability, and reliability in dynamic industrial environments. This conclusion reflects on the achievements, implications, and future directions of the protocol. The protocol integrates advanced optimization techniques and predictive analytics to enhance the efficiency and resilience of WSNs deployed in industrial settings. By dynamically adjusting routing paths based on real-time network conditions and forecasting future states using LSTM networks, the protocol optimizes energy consumption, prolongs sensor

node lifespans, and ensures reliable data transmission. The Hybrid Coot-LS algorithm's ability to balance exploration and exploitation in routing decisions, coupled with LSTM-based DOM prediction's predictive capabilities, enables proactive management of network resources and adaptive routing strategies.

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