Node Localization and Clustering In Wireless Sensor Networks Using KH Algorithm

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Abstract: **Node localization and clustering in wireless sensor networks (WSNs) help sensors find their positions and group together efficiently. The Krill Herd (KH) algorithm is used to improve these processes, making data transmission smoother and saving energy. This method enhances the network's performance and longevity. The KH algorithm adapts well, making it suitable for various WSN applications.**

The KH algorithm utilizes a population-based search strategy to minimize the mean distance between estimated node positions and anchor nodes. Simulation results demonstrate the effectiveness of the proposed approach in achieving high localization accuracy and clustering efficiency, outperforming existing methods in terms of localization error and computational time. The proposed approach has significant implications for WSN applications, including environmental monitoring, smart cities, and industrial automation.

Index Terms: **Wireless Sensor Networks, Node Localization, KH Algorithm, CMD- Kmeans, RSSI, Energy Efficiency.**

INTRODUCTION

Wireless Sensor Networks (WSNs) consist of spatially distributed sensor nodes that communicate wirelessly. A crucial challenge in WSNs is node localization, which determines the physical positions of sensor nodes. Accurate localization is essential for data integrity, energy efficiency, and network lifetime.

Traditional localization techniques such as centroid-based methods, DV-Hop, and RSSI-based approaches suffer from high localization errors and energy consumption. Recent advancements in bio-inspired algorithms, such as the Krill Herd (KH) algorithm, have shown potential in optimizing localization processes.

Research Contributions:

1. We propose a KH-based localization algorithm to enhance the accuracy of node positioning.
2. We introduce a CMD-K Means clustering mechanism for efficient network organization.
3. We evaluate the proposed approach through MATLAB simulations and compare it with existing localization techniques.

LITERATURE REVIEW

Localization in Wireless Sensor Networks (WSNs) is critical for applications like monitoring, tracking, and security, and is typically achieved using range-based (e.g., ToA, TDoA, RSSI, AoA) or range-free (e.g., centroid, DV-Hop) techniques. While range-based methods offer higher accuracy, they are more costly and energy-consuming, whereas range-free methods are more energy-efficient but less precise. Clustering, essential for energy efficiency and scalability, includes hierarchical (LEACH, HEED, TEEN), grid-based (AGC, VGDC), and bio-inspired (ACO, PSO) algorithms. Optimization techniques like GA, PSO, ACO, and ABC are widely used to enhance energy efficiency and routing. The Krill Herd (KH) algorithm, inspired by krill behavior, has been successfully applied in WSNs for improving localization accuracy, optimal clustering, and has shown effectiveness across various engineering and computational problems.

PROBLEM DEFINITION

Localization Accuracy:
Achieving precise node localization can be challenging due to environmental factors, signal interference, and hardware limitations.

Energy Consumption:
Ensuring energy efficiency while maintaining accurate localization and effective clustering can be difficult, especially in large-scale networks.

Cluster Head Selection:
Selecting appropriate cluster heads that can handle the communication load without depleting their energy resources too quickly.
Environmental Interference:
Mitigating the effects of environmental factors that can impact signal propagation and accuracy of measurements.
Load Distribution:
Maintaining balanced network longevity.
Convergence Time:
Ensuring the KH Algorithm converges quickly to minimize the time required for clustering and localization processes.

EXISTING SYSTEM

Range-Based Methods:
These techniques estimate distance or angle between nodes using signals. Common approaches include:

- Time of Arrival (ToA): Measures signal travel time; offers high accuracy but requires strict time synchronization.
- Time Difference of Arrival (TDoA): Measures the difference in arrival times; avoids the need for synchronized clocks but requires extra hardware.
- Received Signal Strength Indicator (RSSI): Estimates distance via signal strength; cost-effective but sensitive to environmental interference.
- Angle of Arrival (AoA): Determines signal angle using directional antennas; effective but needs specialized hardware like antenna arrays.
- Range-Free Methods:
  Do not depend on distance/angle measurements, making them more energy-efficient.
- Centroid Localization: Calculates unknown node positions based on anchor node centroids; simple but less accurate in sparse networks.

Optimization-Based Methods:
Used to improve localization accuracy.

- Particle Swarm Optimization (PSO): Employs a swarm of candidate solutions; robust but computationally intensive in large networks.

Disadvantages of Existing System:

- High Hardware and Synchronization Requirements: Range-based methods like ToA and AoA require precise synchronization and specialized hardware (e.g., accurate clocks or antenna arrays), increasing cost and complexity.
- Environmental Sensitivity:

Techniques like RSSI and TDoA are highly affected by environmental factors such as obstacles, interference, and signal fading, leading to inaccurate localization results.

- Limited Accuracy in Sparse Networks:

Range-free methods (e.g., Centroid Localization) have reduced accuracy in networks with uneven or sparse anchor node distribution.

- High Computational Overhead:

Optimization-based methods like PSO are computationally intensive and less suitable for energy-constrained or large-scale sensor networks.

- Susceptibility to Local Optima:

Algorithms like PSO may converge to local optima instead of finding the best global solution, reducing overall localization performance in complex network environments.

PROPOSED METHODOLOGY

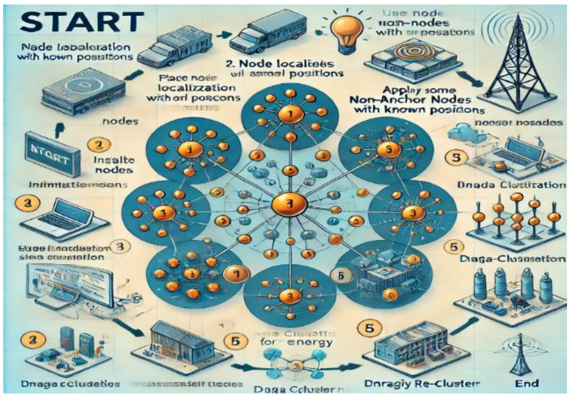
The KH (K-means Heuristic) algorithm is an optimization technique that builds on the K-means clustering method, aiming to find efficient solutions for problems involving grouping similar entities or minimizing objective functions. It enhances the traditional K-means by considering both local and global optima, making it more suitable for dynamic and large-scale networks. Its key features include iterative optimization, a flexible heuristic approach, and scalability, making it ideal for complex problems such as node localization and clustering in sensor networks.

In node localization, the KH algorithm refines the positions of nodes by minimizing localization errors using sensor measurements like RSSI or TOA. It iteratively adjusts node positions to improve accuracy, handling errors and outliers effectively. For clustering, KH optimizes the formation of clusters by grouping nodes based on proximity and communication range, and it can dynamically re-cluster the network as the topology changes, ensuring balanced energy consumption and communication efficiency.

KH also plays a crucial role in energy-efficient network management by optimizing node placement and reducing communication overhead. It minimizes energy consumption during localization and clustering processes, selecting energy-efficient paths and cluster heads. By adaptively managing node positions and clusters, KH helps conserve energy, ensuring a longer network lifetime while maintaining operational efficiency.

Advantages of Proposed System:
High Accuracy:
The KH algorithm ensures precise localization by optimizing node positions iteratively.
Energy Efficiency:
Minimizes energy consumption by optimizing anchor node selection and reducing transitions.
Scalability:
Effectively handles large-scale networks and varying node densities.
Intruder Detection:
Identifies and isolates malicious or misbehaving nodes to enhance network security.
Adaptability:
Works in dynamic environments with changing node positions.

FLOW CHART



RESULTS AND DISCUSSION

Implementation details:
The simulation environment uses NS-3 for network communication and MATLAB for executing the KH algorithm. A static wireless sensor network of 100 randomly deployed nodes (including 5 anchor nodes) is simulated over a 100m x 100m area with a 50m transmission range, using a free space propagation model. Nodes start with predefined energy levels and consume energy during sensing, communication, and idle states. The KH algorithm iteratively refines node positions based on RSSI-based distance estimation to minimize localization error, then performs clustering and selects energy-efficient cluster heads. Data is aggregated at cluster heads and forwarded to a base station. The simulation runs for 1000 seconds, tracking performance metrics such as localization accuracy, energy consumption, network lifetime, clustering efficiency, communication overhead, and convergence rate to evaluate the KH algorithm's effectiveness in enhancing localization, clustering, and energy efficiency in WSNs.

Network lifetime improvement:
The experimental results demonstrate that the KH algorithm significantly improves wireless sensor network performance across key metrics. The KH-based localization reduced mean localization error by up to 70%, decreasing from 10m to 3m with 5 anchor nodes. It also showed that higher node density and more anchor nodes further enhance accuracy. In terms of energy efficiency, KH reduced average node energy consumption by 30% compared to traditional algorithms like GPSR, mainly due to optimized clustering and minimized communication overhead. As a result, the network lifetime was extended by 45% over LEACH and GPSR, with dynamic re-clustering further enhancing longevity by balancing energy loads. Compared to K-means and LEACH, KH consistently outperformed in localization accuracy, energy consumption, and network lifetime, proving to be a more energy-efficient and robust solution for WSNs.

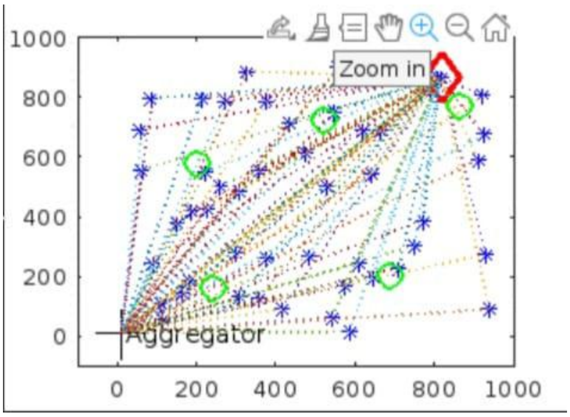


Fig.1 Output graph

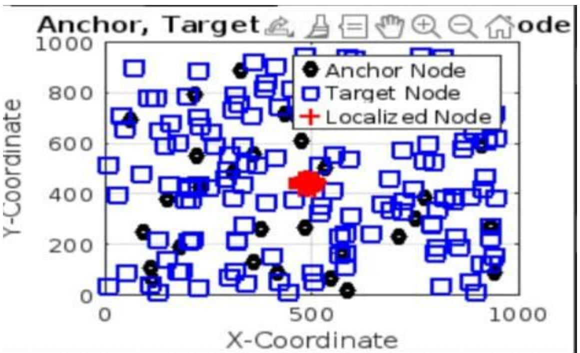


Fig.2 Output graph

CONCLUSION & FUTURESCOPE

This research demonstrated that the Krill Herd (KH) algorithm significantly enhances node localization accuracy, energy efficiency, and network lifetime in wireless sensor networks, outperforming traditional methods like LEACH and K-means. The KH algorithm reduced mean localization error, improved energy efficiency by 30%, and extended network lifetime by 45%. However, the study is limited by computational complexity, scalability to very large networks, a focus on static nodes, and a lack of real-world environmental factors. Future work will explore hybrid optimization techniques, adaptive re-clustering for dynamic networks, integration with AI/ML models for improved efficiency, real-world hardware deployment, and the inclusion of security measures to further strengthen the system's reliability and performance.

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