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Assessing Multi Hop Performance of Reactive Routing Protocol in Wireless Sensor Network

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Abstract- Wireless Sensor Networks (WSNs) are widely used for data collection and monitoring in large-scale environments, where efficient routing is essential to ensure energy conservation, reliability, and extended network lifetime. Traditional multihop routing approaches often face challenges such as uneven energy consumption, high latency, and reduced scalability. In this context, a K-Nearest Neighbors (KNN) based multihop routing strategy is analyzed to improve network performance. The KNN algorithm dynamically selects the most suitable forwarding nodes based on proximity, residual energy, and network topology, thereby balancing the load across the network. Simulation results highlight that the KNN-based routing scheme enhances packet delivery ratio, reduces average communication delay, and minimizes energy consumption compared to conventional protocols. The analysis confirms that KNN-driven multihop routing is a promising approach for optimizing data transmission in WSNs, particularly in dense and energy-constrained environments.

Keywords: Wireless Sensor Networks, Routing Protocols, Cluster Head.

I. INTRODUCTION

Wireless sensor networks constitute spatially distributed sensors to monitor parameters like sound, temperature, vibrations etc. Sensory data comes from the sensors deployed in various locations. Wireless sensor networks perform sensing and processing the sensing data according to the requirement of network. Sensor may register the data on occurrence of event or periodical sensing may be done depending on the application. Industrial application of wireless sensor network is mainly in Industrial process monitoring and controlling machines. Civilian application includes environment and habitat monitoring, health care applications etc. Many applications of wireless sensor networks require smaller node size and smaller node components. Sensor node lifetime depends on battery inside it. Because of wireless nature, applications demand long life of battery, hence energy of sensor nodes must be used very efficiently.

A typical wireless sensor node consist of a sensor unit to perform sensing operations, memory unit for storage of sensed data, battery for power requirements, processor and transceiver for transmitting and receiving of data. Transceiver is provided with limited range antenna and limited memory is provided in sensor node to facilitate smaller size.

Due to technological advances most of traditional industrial wired communication networks today are replaced by wireless sensor networks, since they offer several advantages like fast and ease of installation and maintenance. Industrial wireless sensor networks operate under harsh environment conditions, nodes may also be subjected to radio frequency interference, highly corrosive environment, high humidity levels, dirt, dust and vibrations, which pose major challenge to performance.

Industrial wireless sensor network applications such as industrial process monitoring and control, plant monitoring and factory automation requires reliability and timeliness forwarding. However traditional routing may find limitations in industrial applications due to harshness of environment. Transmission failure in industrial application is unacceptable since it may cause delay or missing of process or control data finally resulting in economic losses.

II. MULTI-HOP ROUTING

Multi-hop communication is a method of data transmission in which information is forwarded through multiple intermediate nodes before reaching the final destination. Unlike single-hop communication, where the source node directly communicates with the sink or base station, multi-hop relies on other nodes to act as relays, passing the data step by step until it arrives at the target. This approach is especially useful in large-scale wireless sensor networks (WSNs) or ad-hoc networks where nodes are spread over a wide area, and direct communication is either not possible or energy-inefficient.

Multi-hop routing improves energy efficiency by reducing the need for long-distance transmissions, increases the coverage area of the network, and enhances reliability by providing alternate paths for data delivery. However, it may also introduce additional delay due to multiple forwarding stages. Overall, multi-hop communication is a scalable and effective solution for modern wireless networks.

Multi-hop routing faces several challenges in underwater IoUT networks. For example, in certain portions of the water environment, there may be links with fast changing data rates, delay, or error rate due to rapid changes in the environment. As such, it would be difficult to make decisions on which node should be a relay and which node should not. In addition, some links may exist only in one direction. This is because a node close to the shore may be able to communicate with a node offshore, but the channel may be too harsh or experience a very high bit error rate in the opposite direction due to the upslope bathymetric profile. A bathymetric profile causes a high number of reflections of equivalent power to the reflected signal. These issues create substantial imbalance in routing paths which has severe effects on multi-hop routing in the IoUT environment. Evolutionary mathematical algorithms may be implemented to address this challenge.

III. TYPES OF WSN MULTIHOP COMMUNICATION

In Wireless Sensor Networks (WSNs), multihop communication means that data is not sent directly from the source to the sink. Instead, it is forwarded through multiple intermediate nodes (hops) until it reaches the sink.

1. Flat-based Multihop Routing

- All nodes play an equal role in the network.
- Data is forwarded hop-by-hop from one node to another until it reaches the sink.
- Simple but may consume more energy.
- Examples: Flooding, Gossiping.

2. Hierarchical (Cluster-based) Multihop

- The network is divided into clusters.
- Each cluster has a Cluster Head (CH).
- Sensor nodes send data to their CH, and the CH forwards it to the sink.
- Improves energy efficiency and scalability.
- Examples: LEACH, PEGASIS.

3. Location-based Multihop

- Data forwarding decisions are based on geographical position of nodes.
- Routing is optimized by considering the distance or coordinates of nodes.
- Useful when node location is known (using GPS or localization).
- Example: GPSR (Greedy Perimeter Stateless Routing).

4. QoS-based Multihop

- Routing is done while considering Quality of Service (QoS) requirements such as delay, reliability, and bandwidth.
- Suitable for real-time and mission-critical applications like healthcare or military.
- Example: SPEED protocol.

5. Energy-aware Multihop

- Focuses on energy conservation to extend the lifetime of WSN.
- Routing paths are selected in such a way that nodes with low energy are avoided, balancing energy consumption.
- Examples: Directed Diffusion, TEEN, HEED.

IV. ROUTE DISCOVERY BASED ROUTING PROTOCOLS

Given the technique used to find the routes, it is sorted to defeat protocols. Routing protocols may commonly be classified as either proactive, reactive, or hybrid, which can join the elements of both proactive and reactive protocols. Routing table data is kept up with and kept through proactive protocols. Then again, course data in receptive protocols are registered on an interesting premise, or at least, at whatever point the hub has information to send. This article is a concise report on routing protocols that remembers data for the reactive routing protocol, an on-demand routing framework. Reactive routing protocols build a route between a source and a destination just when it is important; therefore, they are otherwise called on-request protocols. The AODV and the DSR are two unmistakable sub-protocols that belong to this protocol class. AODV- Ad-hoc On-Demand Distance Vector Routing DSR- Dynamic Source Routing Coming up next is a discussion of the DSR and AODV routing protocol.

V. PROPOSED METHODOLOGY-KNN-BASED MULTIHOP ROUTING IN WSN

- KNN (K-Nearest Neighbor) is a machine learning algorithm that selects the k closest points (neighbors) to make a decision.
- In WSN, this idea is applied for routing:
- Instead of sending data to any random neighbor, each node chooses the k-nearest nodes based on some metric (distance, energy, reliability).
- From those k-nearest, the best candidate node is selected to forward data.

Working Steps

- Neighbor Discovery: Each sensor node identifies its nearby nodes within communication range.
- Distance/Energy Calculation: For each neighbor, compute metrics like distance to sink, residual energy, or link quality.
- Select k Nearest Nodes: Apply the KNN rule → pick k closest neighbors.
- Forwarding Decision: Among those k, choose the most optimal next hop (e.g., shortest distance to sink or highest energy).
- Repeat Until Sink: The process continues hop-by-hop until data reaches the sink.

Advantages

- **Energy Efficiency:** Avoids long-distance transmissions.
- **Reliability**: Can bypass faulty nodes by choosing alternate nearest neighbors.
- **Scalability:** Works well in dense WSNs since many neighbors exist.
- **Load Balancing:** Traffic can be distributed across different k-neighbors instead of always using the same path.

Challenges

- **Overhead:** Each node must compute distances and energy of neighbors.
- **Dynamic Networks:** In mobile WSNs, neighbor lists change frequently.
- **Choice of k:** Wrong k-value may lead to inefficiency (too small → limited choices, too large → more computation).

Example Use Cases

- Smart Agriculture: Routing sensed temperature/moisture data to a base station with minimal energy use.
- Disaster Monitoring: Reliable multihop data delivery when some nodes fail.
- Healthcare WSN: Ensuring low-delay, energy-efficient routing from body sensors to sink.

K-Nearest Neighbors (KNN) is a simple and widely used machine learning algorithm that works on the principle of similarity between data points. It is mainly applied in classification and regression problems. In KNN, when a new data point needs to be predicted, the algorithm calculates its distance from all existing points in the dataset and selects the ‘k’ closest points, known as neighbors. For classification tasks, the new point is assigned to the class most common among its neighbors, while in regression tasks, the output is predicted as the average of the neighbors’ values. KNN does not make assumptions about the data distribution, which makes it a non-parametric algorithm, and it is considered a lazy learner because it does not build a model in advance but performs computation at the time of prediction. Although simple, KNN is powerful and effective in many real-world applications such as pattern recognition, recommendation systems, and intrusion detection.

VI. RESULT AND SIMULATION

In a K-Nearest Neighbor (KNN) based multi-hop routing simulation for Wireless Sensor Networks (WSN), MATLAB can be used to model the deployment of sensor nodes and the routing of data towards the sink node. In this approach, each sensor node does not directly transmit data to the sink; instead, it selects the K nearest neighboring nodes based on Euclidean distance. Among these neighbors, the best next-hop node is chosen according to parameters such as minimum distance, residual energy, or link quality.

This process continues until the data packet reaches the sink node, forming a multi-hop communication path. Using MATLAB, the simulation typically involves random placement of nodes, calculating neighbor distances, applying the KNN algorithm for route selection, and then evaluating the performance in terms of energy consumption, packet delivery ratio, delay, and network lifetime. The advantage of KNN-based multi-hop routing is that it reduces transmission distance per hop, balances energy usage among nodes, and prolongs the overall lifetime of the sensor network compared to direct transmission.

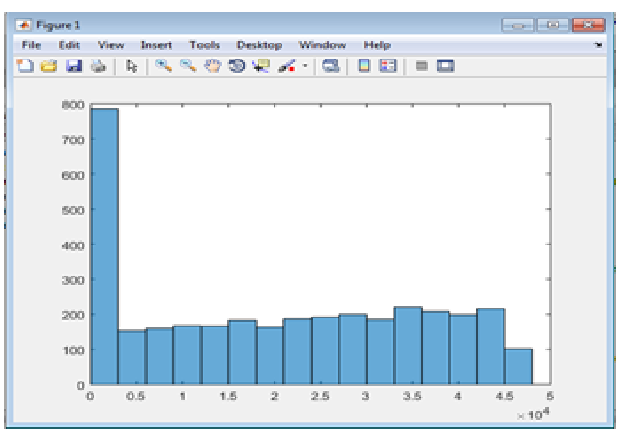

Fig.1. Multi hop Cluster PDR.

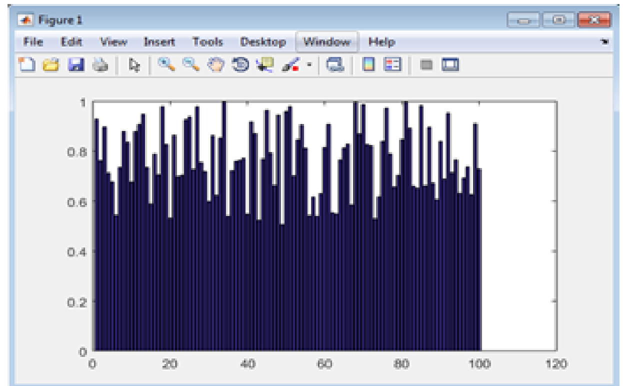

Fig.2. Multi hop Cluster Energy.

VII. CONCLUSION

The simulation of KNN-based multihop routing in Wireless Sensor Networks demonstrates that the use of nearest neighbor selection significantly improves data transmission efficiency compared to traditional multihop protocols. By dynamically choosing the k-nearest nodes for forwarding, the routing process achieves better load balancing, reduces communication delay, and enhances packet delivery ratio. The analysis also shows that KNN-based routing minimizes energy consumption by avoiding long-distance transmissions and distributing traffic evenly among available nodes. Furthermore, the approach adapts well to network topology changes, making it suitable for large-scale and dense WSN deployments. In conclusion, the KNN-based multihop routing strategy provides an energy-efficient, reliable, and scalable solution for WSNs, ensuring extended network lifetime and improved overall performance.

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