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Data Collection in WSNs using a Probability-Based Rendezvous Points Selection Algorithm

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***Abstract*— Wireless Sensor Networks are becoming more prevalent in various industries, including military operations and distant environmental monitoring. This is important because sensors are getting smarter, smaller, and less expensive. The energy hole problem in the WSN has been a major focus of recent research. The mobile sink is an efficient solution for the energy hole problem in a wireless sensor network. A mobile sink gets data from sensors by moving around the network often to avoid problems with hotspots or energy holes. It gets data from network nodes by traveling regularly and visiting a group of nodes known as rendezvous points (RPs). This research will present a probability-based RP selection (PRPS) technique for data collection in wireless sensor networks. To begin, a directed spanning tree is used to construct a tree that eliminates duplication in the data forwarding path. The proposed method is employed to compute the likelihood of RPs. Finally, using the shortest path technique, a mobile sink is constructed between these locations. The path provided is the best path that connects all of the RPs. The proposed approach improves the previous solutions by choosing the nodes with the most data packets as RPs. As a result, it extends network lifetime by lowering energy consumption and addressing the energy hole problem.**

***Keywords*— Rendezvous Point, Wireless Sensor Network, Energy Hole Problem, Mobile Sink.**

I. INTRODUCTION

The WSN is recognized as one of the key components that has contributed significantly to the evolution of computing [1, 2, 3, and 4]. The WSN is made up of nodes and a base station [5]. Each node collects data from its surroundings and sends it to the base station [6,7, and 8]. The WSN is mainly used for monitoring (temperature, pressure, sound, etc.). It is also used in military, medical, and meteorological forecasting [9, 10, and 11].

Even though the WSN has many advantages, the main disadvantage is that it consumes a lot of energy and keeps the sensors from working correctly. It is impossible to replace or supply additional power to the sensor battery [12, 13, 14, and 15]. If the sensors use less energy, they will last longer, making the network last longer and getting the most out of it [16, and 17]. Time-critical applications necessitate constant and quick data delivery and energy efficiency. Data loses its value if it is not received by a specific time, so timing is very important [9].

Data is transferred between nodes and the base station or sink in two ways: single-hop or multi-hop. In the case of a single hop, the node consumes much energy if the base station is far away [18, 19, and 20]. The further the distance between the node and the base station or sink, the more power is used. Also, the multi-hop method cannot be used because it takes too long to reach all nodes in the network [21, 22, and 23]. Nodes near the base station are more influenced than other nodes and require more energy than other sensors because a large amount of data will pass through them. As a result, both strategies are inadequate and contribute to the energy hole problem [24, and 25]. The energy hole issue is a severe threat to the WSN since it disconnects the sink from the rest of the network, causing the data collection process to be terminated [26, and 27]. So, energy must be shared evenly among nodes to make the network last longer and keep data collection going [28]. To overcome these challenges, a mobile sink has been developed to collect data from network nodes by moving regularly; instead of visiting all nodes in WSNs, the mobile sink visits a subset of nodes known as RPs during the defined delay. As a result, the data collection process will be avoided or sped up [29, 30, and 31].

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Virtual rendezvous locations (VRPs), nodes near the mobile sink, are also available. VRPs transfer data directly to the mobile sink rather than to RPs [32]. The primary advantage of picking the best group of VRPs is that it decreases the number of hops required to transmit data between nodes, lowering energy consumption, lost data, network lifetime, and coping with disconnected nodes. Nodes not designated as RPs or VRPs send data to the nearest RP. [24, 33, 34, and 35].

Although RPs and VRPs are great ideas, choosing the greatest collection of RPs and VRPs takes time and effort. Choosing the same node as an RP multiple times during data collection will result in an energy imbalance between the nodes. Determining the best path between RPs, particularly with non-uniform data, is seen as a formidable challenge [36, 37].

This research will concentrate on a PRPS algorithm for data collection to improve network performance in energy utilization.

II. Literature Review

Many works in literature introduced the data collection issue in WSN like [27, 32, 33, 34, 35, and 36]

The authors of [24] proposed improving the ant colony optimization ACO-based mobile sink path identification in a wireless sensor network. They determined the best RPs group and the most efficient mobile sink travel path. They made the probability functions better based on two criteria, and then they used those functions to choose RPs and the mobile sink path. The first parameter is the distance between nodes, while the second is the weight (data load on the node). Using these features helps choose the best group of RPs and reduces the time it takes to tour the mobile sink. They also employed a technique to reselect RPs to solve the problem of energy balancing among RPs. VRPs were created in order to eliminate data collection delays. VRPs reduce the number of sensor linkages because they send data directly to the mobile sink.

In [38], the authors showed how LEACH could be used to make a new routing system for a wireless sensor network. The proposed approach integrates the micro genetic algorithm with the LEACH protocol. It saves WSN energy while extending the WSN lifetime and making the cluster head (CH) selection procedure more powerful than other methods. The proposed protocol performed better than the previous protocols. Other protocols, like LEACH, LEACH-C, LEACH GA, and GADA LEACH, do not do as well in terms of power usage, network life, and choosing the cluster head (CH).

[39] suggested a new routing technique based on variable-dimension Dimension Particle Swarm Optimization (VD-PSO). They defined all possible traveling salesman solutions as particles, with each dimension particle being an RP. An ideal mobile sink path can be obtained using the particle evolutionary approach. The innovative routing method achieves encouraging results in terms of convergence speed to optimal path solution.

The authors of [40] use the ant colony optimization (ACO) method to find the best mobile sink path in clustered wireless sensor networks. They tried to find the best number of sojourn sites to get data from each cluster in just one hop. The shorter tour path saves time on data collection, which lets it avoid the energy hole problem and get a good balance of energy use. Based on the performance evaluation results, the protocol is better than other protocols in terms of how much energy it uses, how long it takes to collect data, and how long the network lasts.

The authors of [41] believe that the MS movement is restricted. They devised a routing scheme with a coverage parameter so that WSN coverage would stay the same even if some sensors stopped working. The proposed method ensures that each sensor sends data to MS quickly and with as little delay as possible. It optimizes network energy and aims to extend the lifetime of the WSN, regardless of the applications that operate within it. The simulation results show how well the routing protocol works compared to other methods, such as how much energy it uses, how long it takes to deliver packets, and how long the network lasts.

[42]'s creators devised an energy-efficient routing technology. They were concerned about the distance between Cluster Heads (CH), which had previously been disregarded in investigations. They developed the DETSSEP (Distance-based Enhance Threshold Sensitive Stable Election technique). In the proposed protocol, the distance factor (the distance between the base station and the sensor) and the node energy are the main things used to choose the cluster head. They use a dual-hop between the base station and the cluster head to ensure that all network parts use the same energy. Enhance Threshold Sensitive Stable Election Protocol (ETSSEP) results are worse than DETSSEP results regarding network lifetime, energy use, consistency, dependability, and throughput.

[43]'s writers were concerned about energy consumption and network lifespan in WSNs. Nodes near the mobile sink spend more energy than other nodes due to the repetitive data transfer, resulting in an energy hole problem and a decrease in WSN lifetime.

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To overcome these difficulties, they presented an energy-efficient data-gathering process for WSN. Using an analytical method, they found a good speed for the mobile data collector (MDC) and a good range for each cluster for sending data. Furthermore, the proposed system automatically configures sensors to eliminate the energy hole problem. The experimental results show an increase in network lifetime compared to alternative techniques.

[44] authors focused on CH selection in diverse WSNs. They demonstrated two heterogeneous WSN approaches. The first protocol is the Genetic Algorithm-based Optimized Clustering (GAOC), while the second is the multiple data Sink-based GAOC (MS-GAOC). Both algorithms' fitness functions include characteristics such as the distance between the mobile sink and the sensor and the remaining energy. They deployed multiple mobile sinks to fill the energy hole. The simulation results reveal that both proposed protocols outperform competing approaches regarding network lifetime, remaining energy, dependability, throughput, energy hole problem, and dead sensors.

The authors of [45] proposed a data fusion technique for heterogeneous WSNs that combines the bat algorithm with extreme ML. They used BATEML to solve issues with the input layer's weight and the hidden layer's threshold. A mobile heterogeneous WSN was employed to collect data, and sensory input was retrieved utilizing extreme LM. All sensor data were merged using extreme ML to reduce the quantity of data sent to the sink node. The experimental results reveal that the proposed approach outperforms other systems, such as the BP neural network, ELM, and Stable Election Protocol, in terms of network lifetime, energy consumption, dependability, and network traffic (SEP).

In [46], the authors offered two unique techniques. The first protocol is the Improved Dual Hop Routing protocol (IDHR), and the second is the Energy Efficient Cluster-based Routing protocol (EECR), which uses numerous data sinks (MEEC). MEEC and IDHR pick the Cluster Head (CH) by integrating the distance between the sensor and the mobile sink, the node density parameter, and energy. They employ many data sinks to prevent hotspots and increase network lifetime by avoiding dual-hop between Cluster Heads and mobile sinks. According to simulation data, both proposed protocols beat current protocols, such as TEDRP, SEECP, and DRESEP.

III. PROPOSED MODEL

To discover RP locations, the proposed algorithm employs a directed spanning tree (DST) as a preamble tree. The primary reason for selecting RP points from all nodes is to find the shortest path between these locations.

The following assumptions are made in the proposed algorithm:

- It is assumed that sensors were randomly distributed throughout a defined area.
- RP nodes and the mobile sink have no storage capacity limits.
- The mobile sink and the base station have access to the sensor's data (location, remaining energy).
- The mobile sink path has no drawbacks.

WSN is represented as a graph G (V, E), where V is a finite collection of homogeneous sensors and E is an edge in graph G connecting two sensors.

A. Directed Spanning Tree Construction

The directed spanning tree aims to build a tree that avoids duplication in the path where data is sent [3]. Through data exchange, neighboring nodes select a forward node. Two rounds are used to generate the tree T from graph G. If the first round generates disconnect nodes, they must be dealt with in a second round. Figure 1 shows how to construct a directed spanning tree. The inner number in figure 1a represents the node's ID, while the outer number represents the node's weight Wi at time t. Node If the forwarding node's "i" weight is the greatest among the surrounding nodes, "i" was chosen in the first round. If the maximum weights of two forwarding nodes are equal, "i" choose the one closest to it. Round 1 produced the tree depicted in Figure 1b. Two isolated nodes were discovered (node one and node 10). Because its weight is greater than the other nodes, node 1 is isolated (2 and 5).

Similarly, node 10 is isolated because its weight exceeds its neighbor's (node 3). A second round is required after round one to connect isolated nodes. There are two distinct nodes (node one and node 10). Isolated node 1 selects node 2 as the forwarding node because it is closer to node 1 than the other nodes. Similarly, node 10 selects node 3 as its forwarding node because it is the closest. As a result, Figure 1c depicts a directed spanning tree.

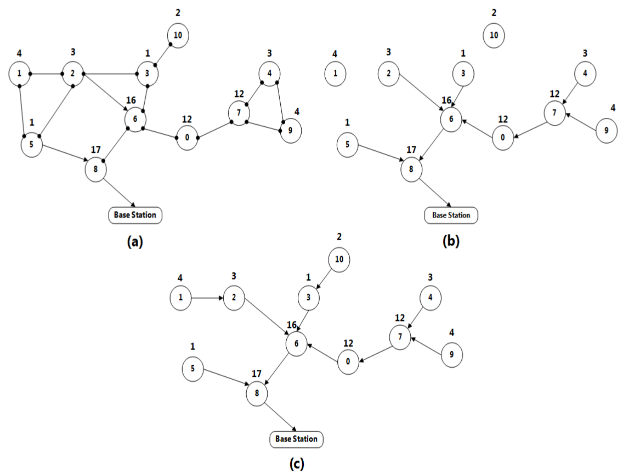

Fig. 1. Illustration to construct a directed spanning tree

A. Proposed Algorithm

For each RP, the PRPS algorithm computes and determines the highest probability. The probability of the RP is found by multiplying the number of hops by the nearest RP and the number of data packets held by the sensor. The result is then multiplied by the amount of energy left in the sensor. The probability formula for the sensor is depicted in Equation (1).

$$P_i = H * D * R \qquad (1)$$

where Pi represents the probability of the sensor, H represents the number of hops, D represents the number of packets, and R represents the remaining energy of the sensor.

The selection probability of nodes that are one hop away from the nearest RP and its buffer is lower than that of other nodes. So, nodes far from a chosen RP and with many packets in their buffer are more likely to be chosen than other nodes. Also, nodes with more energy are more likely to be chosen than nodes with less energy.

Based on how much energy a sensor has left, the number of data packets that need to be sent and the number of hops between a node and its destination change. Accessing the sensors with the highest probability and reducing the hops required to forward data packets can reduce the energy consumption of sensors. As a result, WSNs are supported, energy holes are filled, and the network lasts longer. In addition, congestion may cause the problem of energy holes. Some nodes will perish if numerous sensors are in a small network area.

So, the energy hole problem can be solved by building a mobile sink and sending it through the network at regular intervals to collect data from specific nodes. If these nodes are repeatedly selected, their energy will be quickly depleted. To address this issue, the node's probability should have changed at a specific time. The repeated computation of probabilities will yield distinct probabilities each time, which is advantageous for modifying the preferred RP.

The proposed method starts by using the formula to determine each node's probability (1). The remaining energy of the node, the number of hops to the nearest RP, and the number of data packets it has used to figure out the probability. The result is to construct a directed-span tree with the base station as its root node. The mobile sink tour begins at the base of the data forwarding tree (base station). Following the calculation of probabilities, the most probable node, "A" is added to the tour. The tour length is then determined. If the tour length is less than the maximum preset length, node "A" is considered an RP point and is added to the tour. When the first iteration of the mobile sink is complete, it will appear as follows: M = [BS, A]. Similarly, the preceding procedures are repeated multiple times until the selected RP point meets the preconditions of the tour's maximum predetermined length.

TABLE I
BASED RENDEZVOUS POINTS SELECTION ALGORITHM

Input	G(V, E), Lmax
Output	S = {s0, s1, s2... sn}, where si ∈ V.
Processes	1. Set the base station as the first RP point in set S. 2. Construct the shortest path tree with the base station as a tree root node 3. Compute the load of data packets for each node, the hops between each node and its closest RP point, and the node's remaining energy. 4. Based on step '3' compute the probability value for each node in the network 5. Determine the node with the highest probability, allocate it as an RP point, and append it to the set S. 6. By employing an SPT solver computes the length of the tour. 7. The length of the tour is accepted if it is less than the maximum predefined length of the tour. 8. Otherwise, the RP point is eliminated from the set S, and proceeds to the next RP point and repeats the same steps.

Figure 2 shows the processes used to determine the path for the mobile sink by using the PRPS algorithm for data collection in WSN.

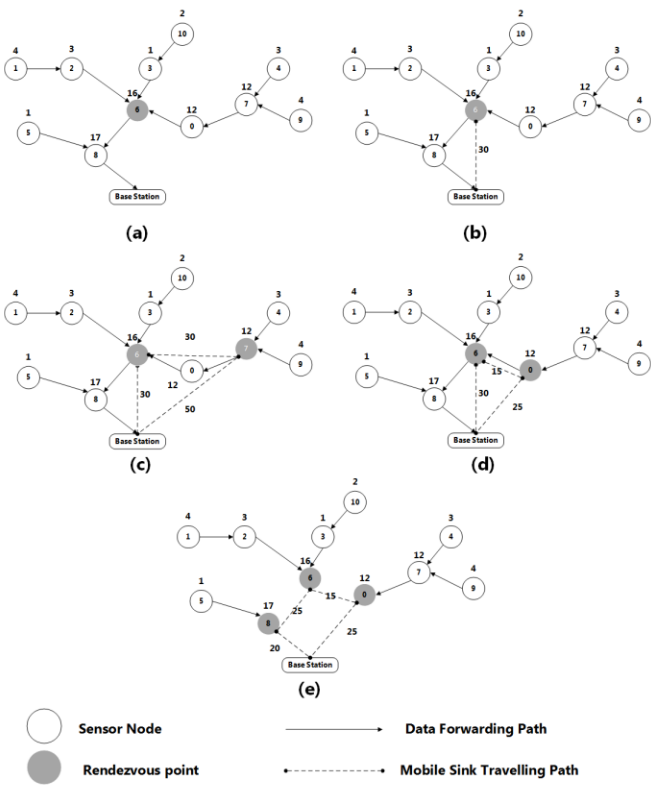

Fig. 2. Illustration of The PRPS Algorithm

The distances listed below indicate the Euclidean distance between nodes in Figure 2.

- The distance between the base station and Node 0 is 25 meters.
- The distance between the base station and Node 6 is 30 meters.
- The distance between the base station and Node 7 is 50 meters.
- The distance between Node 6 and Node 0 is 15 meters.

First, it is assumed that the tour's maximum length is Lmax = 90. The PRPS algorithm begins at the base station and adds to the tour; therefore, S = [BS]. Then, the shortest path tree is constructed with the base station as the root node.

After computing the probabilities for each node, node 6 has the highest probability value in iteration 1. Consequently, node 6 is added to the tour: S = [BS, 6].

Calculating the tour length of the sink reveals that the tour length of S is shorter than the assumed tour length (6090). Consequently, node 6 remains on tour.

The second time through, the probability calculation is repeated because node 6 is part of the tour. The highest probability value is assigned to Node 7. Therefore, node 7 is added to the tour: S = [BS, 6]. After calculating the sink's tour duration, it is determined that S's tour length exceeds the assumed length (110 > 90). Thus, node 7 is eliminated from the tour: S= [BS, 6].

Node 7 does not meet the criteria for an RP point, so the probability calculation is skipped in iteration three. Node 0 has the next-highest probability value. As a result, node 0 is added to tour S = [BS, 6, 0]. When the tour length for the sink is calculated, it is discovered that S has a shorter tour length than anticipated (70>90). Consequently, node 0 remains within the tour.

Iteration four involves recalculating the probability without nodes 6 and 0 because the tour requires them. The highest probability is attributed to Node 8. Thus, node 8 is added to the tour S = [BS, 8, 6, 0]. After calculating the sink's tour length, it is determined that S's tour length is shorter than expected (85>90). As a result, node 8 remains on tour.

Figure 2e depicts the final leg of the journey. The node with the most data packets joins the last tour and becomes a member first. Consequently, it maintains a consistent energy consumption across all sensors and reduces the issue of energy gaps. This is the proposed method's primary benefit compared to other approaches.

At each iteration of data collection, each node's probability must be determined and transmitted to the base station. As a result of these computations, the tour path is calculated, and all nodes are notified to transfer their data to the RP points. The probability calculation is performed for each tour to determine the tour's path. The base station transmits tour path information to all nodes. Therefore, all nodes, not just RP points, transmit their data to the nearest RP point, which then transmits it to the mobile sink. The mobile sink then visits each RP point to collect data, uploads it to the base station, and prepares for the subsequent round.

The proposed algorithm outperforms the alternatives because it selects RP points with more data packets, a greater distance from the nearest RP point, and greater remaining energy. Consequently, it increases the network's lifetime by reducing energy consumption and resolving the energy hole issue.

This algorithm reduces energy consumption by visiting nodes with a high probability rather than nodes with a low probability because nodes with a high probability have more data packets to be forwarded (including their child's packets), have more remaining energy, and exist at a distance further than one hop away. Consequently, the number of hops required to transmit data over a long distance decreases. In addition, energy consumption is decreased when the nodes with the highest probability send their data to the mobile sink because it reduces the number of network hops required for long-distance communication.

IV. Conclusion

In WSNs, a PRPS algorithm for data collection was proposed. By selecting a set of RP points, the suggested method provided an efficient energy consumption strategy. A mobile sink was made to get data from network nodes by going to each RP point regularly. The path selected is the optimal path that connects all RP spots. Furthermore, the proposed method aided the data-gathering procedure at each RP point with the best tour path length. The likelihood of the RPs is calculated using three parameters. The parameters used to choose an RP point were the number of hops between the node and its closest RP point, the node's remaining energy, and the node's data. The suggested technique beats the other approaches because it chooses nodes with the most data packets as RP points. This algorithm reduces energy usage by visiting nodes with a high probability rather than nodes with a low probability because the nodes with the highest probability have more data packets to be transmitted (including the packets of their child). As a result, the number of hops required to send data over a long distance is reduced.

Additionally, energy consumption is reduced when the nodes with the highest probability transfer their data to the mobile sink. Because it reduces the number of hops required for long-distance communication within the network, it extends the network's life by using less energy and fixing the problem of energy holes.

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