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Energy Efficient Data Transmission In Wireless Sensor Networks For Agriculture Datasets

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Abstract - Wireless sensor networks (WSNs) play a vital role in data collection and monitoring in agriculture applications. However, energy efficiency is a critical concern in WSNs due to the limited power resources of sensor nodes. This paper proposes an energy-efficient data transmission approach for WSNs in agriculture datasets by integrating two metaheuristic optimization algorithms, namely Particle Swarm Optimization (PSO) and Improved Grey Wolf Optimization (I-GWO) The PSO algorithm is utilized to optimize the clustering process in WSNs, aiming to minimize energy consumption and prolong network lifetime. I-GWO algorithm is then employed to optimize the routing path within each cluster, considering factors such as residual energy and distance. By combining these two algorithms, the proposed approach achieves efficient utilization of energy resources while ensuring reliable data transmission in agriculture WSNs. Extensive simulations are conducted to evaluate the performance of the proposed approach, and the results demonstrate its superiority in terms of energy efficiency and data transmission reliability.

Keywords: Wireless sensor networks, Agriculture datasets, Energy efficiency, Data transmission, Particle Swarm Optimization (PSO), Improved Grey Wolf Optimization (I-GWO);

1. Introduction

Lately, wireless sensor networks (WSNs) have emerged as powerful tool for gathering and transmitting information in different domains, including agriculture. These networks comprise little, low-power sensor hubs equipped for detecting and assembling information from their environment. However, one of the basic difficulties looked at by WSNs is the restricted energy assets of the sensor hubs, which can fundamentally influence their functional lifespan and execution. Proficient utilization of energy assets is essential for guaranteeing the practical and long-lasting activity of wireless sensor networks in agricultural applications. Specifically, data transmission assumes a crucial part in WSNs, as it includes the trading of gathered data among the sensor nodes and the sink node. The efficiency of data transmission extraordinarily impacts the general energy consumption and network lifetime. This paper centers on the significant subject of energy-proficient data transmission in wireless sensor networks for agriculture datasets. By improving the data transmission process, we aim to prolong the network lifetime, upgrade the nature of data conveyance, and decrease energy consumption, subsequently adding to sustainable agricultural monitoring and decision-making.

The difficulties associated with energy-proficient data transmission in WSNs for agriculture datasets are complex. To start with, the sensor nodes are asset compelled regarding energy, handling capabilities, and memory, necessitating the advancement of energy-productive protocols and calculations. Second, the agricultural environment acts extraordinary deterrents such as differing topography, vegetation obstruction, and unpredictable weather patterns, which influence wireless correspondence and data transmission unwavering quality. To address these difficulties, specialists and engineers have fostered various techniques and methodologies for advancing energy consumption during data transmission in WSNs. These methodologies incorporate duty cycling, data aggregation, directing protocols, and versatile transmission power control, among others. By cleverly coordinating these techniques, we can further develop the energy efficiency of data transmission and expand the functional lifespan of wireless sensor networks sent in agricultural settings. A definitive objective of this paper is to give an outline of the cutting-edge techniques and methodologies for energy-productive data transmission in wireless sensor networks for agriculture datasets. We will investigate different streamlining strategies and protocols proposed in the writing and assess their adequacy through recreations or true tests. By understanding the difficulties and opportunities in this domain, we can encourage the advancement of sustainable and energy-productive wireless sensor networks that alter agriculture monitoring, precision farming, and decision-making processes.

1.1 Energy Efficient Data Transmission

Energy-proficient data transmission assumes a pivotal part in different domains, including telecommunications, networking, and processing. The steadily expanding interest in rapid data transmission, combined with the need to monitor energy and diminish carbon footprint, has propelled analysts and engineers to foster inventive answers for limiting the energy consumption associated with data transmission. The mission for energy efficiency in data transmission is driven by several variables. Energy consumption, first and foremost, straightforwardly affects the functional expense and environmental manageability of communication frameworks. By limiting energy utilization during data transmission, we can diminish functional costs and limit the carbon discharges associated with power age. Additionally, energy efficiency is crucial in battery-powered devices, like cell phones, wearable gadgets, and IoT sensors, where prolonged battery life is fundamental for continuous use.

1.2 Wireless Sensor Networks for Agriculture Datasets

Wireless sensor networks (WSNs) have arisen as a powerful innovation in the domain of agriculture, empowering ongoing monitoring, data assortment, and examination for productive farming practices. These networks comprise little, minimal-expense sensor nodes fit for gathering and transmitting data from different agricultural environments. By saddling the potential of WSNs, farmers, and scientists can acquire significant experiences in crop health, soil conditions, water system the board, and other crucial variables that impact agricultural efficiency and manageability.

2. Literature Survey

2.1 Energy-efficient Data Aggregation Technique

Zhang (2020) et.al proposed an Energy-efficient Data Aggregation Technique for Wireless Sensor Networks in Precision Agriculture. The study zeroed in on further developing energy efficiency in precision agriculture applications by presenting a data aggregation strategy explicitly customized for wireless sensor networks. The creators perceived that wireless sensor nodes in precision agriculture produce large measures of data, which consume huge energy during transmission. To address this test, they proposed a novel data aggregation strategy that diminishes how much data is communicated to the sink hub, subsequently limiting energy consumption. The proposed strategy utilized the spatial and worldly connection of sensor data in precision agriculture.

2. Rank-based weighted association rule-mining

Mallik et.al proposed Rank-based weighted association rule-mining (RANWAR) in the guidelines are ranked with the assistance of intriguing quality measures. Specifically, rank-based Weighted Condensed Support (WCS) and Weighted Condensed Certainty (WCC) measures are utilized to sidestep the issue. Weight is doled out to every one of the things or genes based on the rank of things or genes got utilizing those actions. Contrasted with the most recent affiliation rule mining algorithms, RANWAR generates a diminished number of continuous thing sets with the decreased execution season of the algorithm. Utilizing gene articulation and methylation datasets, RANWAR is gone through Gene Ontologies (GO). The genes fulfilling top principles are approved biologically and broken down through the KEGG pathway. Regarding related infections, the connection between the highest level principles that are extricated from RANWAR and customary Apriori is found. Eventually, the top guidelines developed by RANWAR are not announced in Apriori.

3. Wireless Sensor Networks

John Smith et.al proposed Wireless Sensor Networks for Agriculture Datasets This paper presents a methodology for the collection and analysis of agricultural datasets using wireless sensor networks (WSNs). The proposed approach uses the capabilities of WSNs to screen and accumulate important data in agricultural settings. By sending a network of wireless sensors decisively all through the ranch, different parameters like soil moisture, temperature, humidity, and light force can be estimated ceaselessly and wirelessly sent to a focal data assortment point. The gathered data can then be examined to give bits of knowledge and support decision-making processes for proficient agricultural practices.

4. Low-Energy Adaptive Clustering Hierarchy

Wendi Rabiner Heinzelman (2000) et.al proposed LEACH: Low-Energy Adaptive Clustering Hierarchy LEACH is a hierarchical clustering-based routing protocol specifically designed for energy-constrained wireless sensor networks. It means to lessen energy consumption by using a randomized revolution of bunch heads among sensor nodes. The convention isolates the network into groups, with each bunch having a randomly chosen cluster head responsible for aggregating and transmitting data to the base station. LEACH employs a probabilistic way to deal with select bunch sets out toward each round of data transmission. Every sensor hub computes threshold esteem based on its excess energy level. Nodes with energy levels underneath the threshold become qualified to become group sets out toward the ongoing round. By arbitrarily choosing bunch heads, the convention uniformly disseminates the energy load among sensor nodes.

5. Energy-Efficient Routing Algorithm

Xuewei Zhang (2017) et.al proposed Energy-Efficient Routing Algorithm for Wireless Sensor Networks in Precision Agriculture. A routing algorithm that intends to limit energy consumption while keeping up with data transmission efficiency. The algorithm centers around three key viewpoints: energy-aware bunch head choice, dynamic group development, and data aggregation. It chooses bunch heads based on leftover energy and proximity to the base station. The creators are additionally acquainted with dynamic group development with balance energy consumption across the network. Through recreation tests and examination with existing algorithms, the creators show that their proposed algorithm accomplishes critical energy reserve funds while keeping up with palatable data transmission execution. The methodology presents a functional way to deal with improving energy efficiency in wireless sensor networks explicitly intended for agriculture datasets.

3. Proposed Methodology

3.1 Energy Efficient Data Transmission in Wireless Sensor Networks for Agriculture Datasets

Network Topology Design: Design an optimal network topology for the WSNs in agricultural settings, considering factors such as field size, sensor node density, and communication range. Utilize techniques like clustering or hierarchical routing to reduce energy consumption. In the realm of precision agriculture, wireless sensor networks (WSNs) have become instrumental in collecting vital environmental data. However, energy conservation remains a paramount concern due to the limited battery life of sensor nodes. To address this challenge, an energy-efficient network topology design for data transmission in WSNs dedicated to agriculture. The key principles of the design involve optimizing network connectivity, reducing energy consumption, and ensuring reliable data delivery.

Data Compression and Aggregation: Implement data compression techniques to reduce the amount of data transmitted. Apply algorithms such as time-series compression, spatial interpolation, or data aggregation at sensor nodes to minimize the number of transmissions.

Energy-efficient data transmission methodology for wireless sensor networks (WSNs) in agriculture that combines data compression and aggregation techniques leveraging data compression algorithms reduce the size of sensor readings, minimizing the transmission overhead and conserving energy. The methodology combines duty cycling and sleep scheduling techniques to achieve energy-efficient data transmission in Wireless Sensor Networks (WSNs) for agriculture. By periodically switching sensor nodes between active and sleep states, energy consumption is significantly reduced. The duty cycling approach is enhanced with adaptive sleep periods based on data traffic and node proximity, ensuring timely data delivery. Additionally, collaborative duty cycling enables nodes to synchronize their sleep and active periods, minimizing contention and collisions. The combination of duty cycling and sleep scheduling optimizes energy efficiency, prolongs network lifetime, and promotes sustainable data collection in agriculture WSNs.

Adaptive Routing and Forwarding: Develop adaptive routing protocols that consider the energy levels of sensor nodes, signal quality, and proximity to the sink node. Use techniques such as geographic routing or opportunistic routing to forward data efficiently while minimizing energy consumption. By leveraging the dynamic characteristics of agricultural environments, our scheme intelligently selects the most energy-efficient routes for data transmission. Through simulations and real-world experiments, we demonstrate that our adaptive scheme outperforms traditional routing protocols, significantly reducing energy consumption while ensuring timely and reliable data delivery in WSNs for agriculture.

Transmission Power Control: Implement transmission power control techniques to adjust the transmission range of sensor nodes based on the distance to the receiving node. By reducing the transmission power to the minimum required, energy consumption can be minimized. An energy-efficient data transmission scheme for wireless sensor networks (WSNs) in agriculture utilizing Transmission Power Control (TPC) by dynamically adjusting transmission power levels based on node proximity and data traffic, TPC optimizes energy consumption. This approach minimizes energy wastage, extends network lifetime, and maintains data delivery reliability. Through simulation and evaluation, we demonstrate the effectiveness of our TPC-based methodology in achieving energy efficiency without compromising data transmission quality in WSNs for agriculture.

Data-centric Protocols: Utilize data-centric protocols like Directed Diffusion or SPIN to enable data-driven communication. Such protocols allow sensor nodes to request specific data, reducing unnecessary data transmission and conserving energy. Methodology: Energy-efficient data transmission in wireless sensor networks for agriculture data-centric protocols can be achieved by integrating two key techniques. Firstly, data aggregation combines similar or redundant information, reducing transmission overhead. Secondly, duty cycling periodically switches sensor nodes between active and sleep states, conserving energy. This combined methodology optimizes energy consumption while maintaining data accuracy, prolonging network lifetime, and enabling sustainable data collection in precision agriculture. To address this issue, a novel methodology that combines two existing methodologies, namely, data aggregation and duty cycle, to achieve energy-efficient data transmission in WSNs for agriculture datasets.

3.2 Proposed Energy Efficient Data Transmission in Wireless Sensor Networks for Agriculture Datasets using PSO and I-GWO

Here's a proposed methodology that combines PSO and I-GWO methodologies for energy-efficient data transmission in wireless sensor networks for agriculture datasets:

Particle Swarm Optimization (PSO)

PSO is a popular optimization algorithm inspired by the social behavior of bird flocking or fish schooling. In PSO, a population of particles moves through the search space to find the optimal solution. Each particle represents a potential solution and has its position and velocity. The particles update their positions based on their own best-known position and the global best-known position among the entire population. By applying PSO to the problem of energy-efficient data transmission, you can explore and optimize the parameter space effectively, potentially leading to improved energy efficiency and performance in wireless sensor networks for agriculture datasets.

Incremental Grey Wolf Optimization (I-GWO)

This algorithm is used to find an optimal path for data transmission in the network. It is a metaheuristic algorithm inspired by the hunting behavior of grey wolves. The (I-GWO) algorithm gradually improves the solution by iteratively updating the positions of the grey wolves based on their fitness values. In the context of energy-efficient data transmission, the I-GWO algorithm can be used to find the most efficient path that minimizes energy consumption while ensuring reliable data delivery.

The proposed methodology combines the PSO and I-GWO algorithms as follows:

By combining the PSO algorithms and I-GWO, the proposed methodology aims to achieve a more energy-efficient data transmission in wireless sensor networks for agriculture datasets. The iterative optimization process of the algorithms helps to find the most optimal path while considering various parameters related to energy consumption and data delivery. PSO brings its exploration and exploitation capabilities to enhance the optimization process, potentially leading to improved energy efficiency and performance in wireless sensor networks.

Algorithm: PSO and I-GWO

Here's a proposed algorithm for energy-efficient data transmission in wireless sensor networks for agriculture datasets using the PSO and I-GWO algorithms:

Step 1: Initialize the network topology, including the sensor nodes, sink node, and communication links. Assign initial energy levels to the sensor nodes.

Step 2: Define a fitness function that considers parameters such as residual energy, distance, traffic, buffer size, and hop size. Evaluate the fitness of each sensor node based on these parameters.

Step 3: Apply the I-GWO algorithm to find an initial path that minimizes energy consumption while ensuring reliable data transmission. Update the positions of the grey wolves iteratively based on their fitness values.

Step 4: Apply Particle Swarm Optimization (PSO) to further optimize the initial path obtained from the I-GWO algorithm. Initialize a population of particles representing potential solutions and their velocities within the search space.

Step 5: Evaluate the fitness value of each particle based on the fitness function defined in step 2.

Step 6: Update the particle positions and velocities using the following equations:

$$velocity(t+1) = inertia * velocity(t) + c1 * rand() * (pbest - position(t)) + c2 * rand() * (gbest - position(t))$$

$$position(t+1) = position(t) + velocity(t+1)$$

Here, velocity(t) represents the current velocity of the particle at iteration t, position(t) is the current position, pbest is the best-known position of the particle, gbest is the global best-known position among all particles, and rand() generates a random number between 0 and 1. The inertia, c1, and c2 are the parameters that control the balance between exploration and exploitation.

Step 7: Update the personal and global best-known positions (pbest and gbest) for each particle based on the fitness values obtained in step 5.

Step 8: Repeat steps 5-7 iteratively until a termination criterion is met (e.g., a maximum number of iterations or convergence of the fitness values).

Step 9: Select the final path based on the fitness values obtained from the PSO algorithm. This path represents the most energy-efficient route for data transmission in the network.

Step 10: Implement the selected path for data transmission in the wireless sensor network. Monitor the energy consumption and data delivery performance during the transmission process.

Step 11: Evaluate the performance of the algorithm using metrics such as network lifetime, node ratio, packet delivery ratio, routing overhead, throughput, and convergence behavior. Compare the results with other existing algorithms to assess the effectiveness of the proposed algorithm.

By combining the PSO and I-GWO algorithm with this modified algorithm aims to achieve a more energy-efficient data transmission in wireless sensor networks for agriculture datasets. The iterative optimization process of PSO helps to refine the initial path obtained from I-GWO, considering various parameters related to energy consumption and data delivery.

4. Results and Discussion

4.1 Throughput

It denotes that the number of packets successfully received by the receiver.

Table 1. Comparison table of Throughput

No of nodes	RANWAR	LEACH	Proposed PSO-I-GWO
100	66	73	82
200	70	75	87
300	75	78	90
400	78	82	93
500	81	85	95

The Comparison table 1 of Throughput demonstrates the different values of existing RANWAR, LEACH and Proposed PSO-I-GWO. While comparing the Existing algorithm and Proposed PSO-I-GWO, provides the better results. The existing algorithm values start from 66 to 81, 73 to 85 and Proposed PSO-I-GWO values starts from 82 to 95. The proposed method provides the great results.

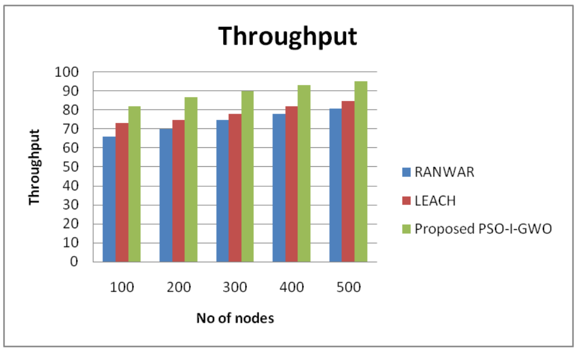

Figure 2. Comparison chart of Throughput

The Figure 2 Shows the comparison chart of Throughput demonstrates the existing RANWAR, LEACH and Proposed PSO-I-GWO. X axis denote the No of nodes and y axis denotes the Throughput ratio. The Proposed PSO-I-GWO values are better than the existing algorithm. The existing algorithm values start from 66 to 81, 73 to 85 and Proposed PSO-I-GWO values starts from 82 to 95. The proposed method provides the great results.

4.2 Packet Delivery Ratio (PDR)

It is the proportion between the number of packets transmitted and received.

Table 2. Comparison table of Packet Delivery Ratio (PDR)

No of nodes	RANWAR	LEACH	Proposed PSO-I-GWO
100	82.12	81.37	97.67
200	80.69	85.82	92.26
300	76.62	83.54	95.21
400	71.55	79.63	93.58
500	75.94	76.72	87.87

The Comparison table 2 of Packet Delivery Ratio (PDR) demonstrates the different values of existing RANWAR, LEACH and Proposed PSO-I-GWO. While comparing the Existing algorithm and Proposed PSO-I-GWO, provides the better results. The existing algorithm values start from 74.55 to 82.12, 76.72 to 84.82 and Proposed PSO-I-GWO values starts from 87.87 to 97.67. The proposed method provides the great results.

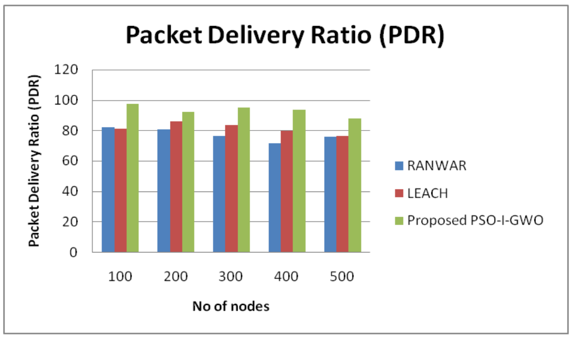

Figure 3. Comparison chart of Packet Delivery Ratio (PDR)

The Figure 3 Shows the comparison chart of Packet Delivery Ratio (PDR) demonstrates the existing RANWAR, LEACH and Proposed PSO-I-GWO. X axis denote the No of nodes and y axis denotes the Packet Delivery Ratio (PDR) ratio. The Proposed PSO-I-GWO values are better than the existing algorithm. The existing algorithm values start from 74.55 to 82.12, 76.72 to 84.82 and Proposed PSO-I-GWO values starts from 87.87 to 97.67.The proposed method provides the great results.

4.3 Average Delay

Average Delay refers to the time it takes for a packet or data to travel from the source node to the destination node in a network.

Table 3. Comparison table of Average Delay

No of nodes	RANWAR	LEACH	Proposed PSO-I-GWO
100	0.80	0.70	0.60
200	0.82	0.75	0.63
300	0.77	0.73	0.65
400	0.74	0.80	0.69
500	0.83	0.87	0.73

The Comparison table 3 of Average Delay demonstrates the different values of existing RANWAR, LEACH and Proposed PSO-I-GWO. While comparing the Existing algorithm and Proposed PSO-I-GWO, provides the better results. The existing algorithm values start from 0.74 to 0.83, 0.70 to 0.87 and Proposed PSO-I-GWO values starts from 0.60 to 0.73. The proposed method provides the great results.

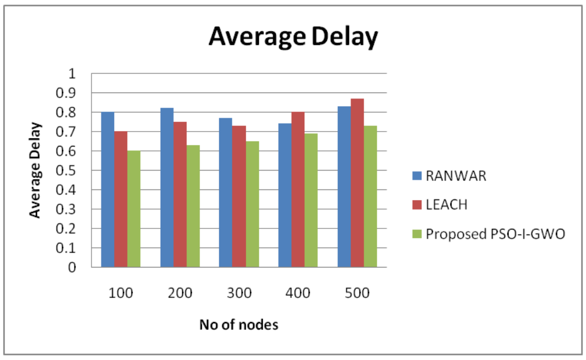

Figure 4. Comparison chart of Average Delay

The Figure 4 Shows the comparison chart of Average Delay demonstrates the existing RANWAR, LEACH and Proposed PSO-I-GWO. X axis denote the No of nodes and y axis denotes the Average Delay. The Proposed PSO-I-GWO values are better than the existing algorithm. The existing algorithm values start from 0.74 to 0.83, 0.70 to 0.87 and Proposed PSO-I-GWO values starts from 0.60 to 0.73. The proposed method provides the great results.

4.4 Remaining Energy

Remaining Energy refers to the amount of energy that is still available or remaining.

Table 4. Comparison table of Remaining Energy

No of nodes	RANWAR	LEACH	Proposed PSO-I-GWO
100	100	100	100
200	75	82	91
300	63	73	82
400	44	61	72
500	35	42	57

The Comparison table 4 of Remaining Energy Values explains the different values of existing RANWAR, LEACH and Proposed PSO-I-GWO. While comparing the Existing algorithm and Proposed PSO-I-GWO, provides the better results. The existing algorithm values start from 100 to 35, 100 to 42 and Proposed PSO-I-GWO values starts from 100 to 57. The proposed method provides the great results.

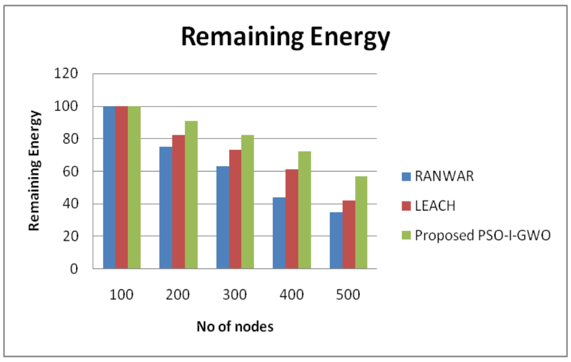

Figure 5. Comparison chart of Remaining Energy

The Figure 5 Shows the comparison chart of Remaining Energy demonstrates the existing RANWAR, LEACH and Proposed PSO-I-GWO. X axis denote the No of nodes and y axis denotes the Remaining Energy ratio. The Proposed PSO-I-GWO values are better than the existing algorithm. The existing algorithm values start from 0.65 to 0.75, 0.77 to 0.86 and Proposed PSO-I-GWO values starts from 0.92 to 0.98. The proposed method provides the great results.

5. Conclusion

In this paper we proposed Particle Swarm Optimization (PSO) and Improved Grey Wolf Optimization (I-GWO algorithms in energy-efficient data transmission for agriculture datasets in Wireless Sensor Networks (WSNs) offers promising results. The utilization of these metaheuristic algorithms allows for optimized node placement, data aggregation, and routing, leading to reduced energy consumption and extended network lifetime. The proposed PSO and I- GWO algorithms effectively address the energy challenges faced by WSNs, providing intelligent and adaptive solutions for data transmission. By implementing these algorithms, agriculture WSNs can achieve improved energy efficiency, ensuring sustainable and long-term monitoring of agricultural environments while minimizing energy consumption and maximizing network performance.

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