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Enhanced Network Lifetime with EPMS: An Energy-Aware PSO Based Routing Algorithm with Mobile Sink Support for Hot Spot Mitigation in WSNs

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Abstract: Wireless sensor networks (WSNs) often face hot spot problems, where sensor nodes near the sink node handle higher data volumes during transmission, leading to energy depletion and bottleneck issues. Utilizing mobile sink nodes with clustering algorithms is a promising approach to enhance the energy efficiency, network lifetime, and overall performance of wireless sensor networks. Furthermore, the integration of nature-inspired algorithms with the mobile sink strategy has enhanced network performance in terms of latency, energy efficiency, and mobility. Our paper presents a novel clustering algorithm based on the particle swarm optimization (PSO) technique, utilizing mobile sink nodes to mitigate hot spot problems in WSNs. Our proposed EPMS (Energy- aware PSO based routing algorithm with Mobile Sink support) incorporates a virtual clustering technique during the routing process, leveraging the PSO algorithm. The selection of cluster heads is based on key parameters such as residual energy and node position. A well-designed control strategy is employed to enable the mobile sink to efficiently collect data from cluster heads. Simulation results demonstrate that the proposed algorithm offers significant improvements in extension of network performance, expenditure of energy, and reduced transmission delays as compared to several commonly used routing algorithms. By integrating the PSO technique and mobile sink nodes, this research contributes to addressing the hot spot problem in WSNs, offering enhanced network performance and sustainability.

Keywords: *Mobile Sink, Clustering Algorithm, Hot Spot Problem, Particle Swarm Optimization, WSNs, EPMS.*

1. Introduction

Information and communication technology (ICT) is playing an important role in mobile communication with the rapid growth of smart cities and the Internet of Everything (IoE). Wireless sensor networks (WSNs) offer a novel approach for collecting, processing and communicating data among various devices, such as RFID tags, sensors, and actuators [1]. WSNs typically consist of hundreds or even thousands of sensors that form a network for monitoring a specific region and providing feedback to end-users regarding the desired targets or events. The WSNs are composed of small, cheap, and battery-operated sensor devices which work in a multi-dimensional area. The applications of WSNs are diverse and wide-ranging [2]. They can be deployed for military tracking and surveillance, enabling efficient personnel and equipment monitoring. WSNs are also valuable in natural disaster relief, where they can aid in assessing affected areas and facilitate timely and targeted response efforts [3].

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Additionally, WSNs find utility in hazardous environment exploration, where they can be deployed to gather data in environments that may be unsafe for human presence. Furthermore, WSNs contribute to health monitoring initiatives, enabling continuous remote monitoring of vital signs and health-related parameters [4]. WSNs offer a versatile and scalable data collection and communication solution, making them applicable in various domains and as a crucial component of the ICT infrastructure supporting smart cities and IoT applications. Many sensors are deployed throughout the monitoring area to ensure effective communication and network connectivity in wireless sensor networks (WSNs). This prevents the network from dividing into isolated regions, providing complete data transmission among nodes [5].

Traditional WSNs transmit information to a central sink node multi-hop to reduce energy consumption. While multi-hop communication helps conserve energy somewhat, it also introduces certain issues. One well-known problem is the hot spot problem [6]. This problem arises because sensor nodes closer to the sink have to transmit their own data and data from other nodes. As a result, these nodes' energy consumption is higher than other nodes in the network [7]. Consequently, these nodes will likely deplete their energy resources faster, leading to premature node failure. This, in turn, can cause network partitioning and reduce the overall network lifetime. The hot spot problem is a significant challenge in WSNs, affecting the network's stability and longevity [8]. Addressing this problem ensures reliable and efficient data transmission throughout the network. Various techniques, such as introducing mobile sink nodes, optimizing routing algorithms, and implementing energy-aware protocols, have been proposed to mitigate the hot spot problem and extend the network lifetime [9]. Introducing sink mobility into wireless sensor networks (WSNs) has been recognized as an effective approach to mitigating the hot spot problem and balancing energy consumption. Including mobile nodes in WSNs presents both new right set of circumstances and probabilities, and it can also upgrade the unambiguousness of node positioning [10]. By incorporating a mobile sink node, the network topology in WSNs becomes dynamic, and it allows flexible data transmission. This means the network load is no longer concentrated solely on the nodes close to the fixed sink [11].By leveraging the mobility of the sink node in a strategic and intelligent manner, load balancing can be achieved more effectively, and the hot spot problem in WSNs can be mitigated

[12].

The use of a mobile sink node brings several advantages:

1. It helps distribute the energy consumption more evenly among the sensor nodes, extending the network lifetime.

2. It enhances the positioning accuracy of nodes by enabling more accurate localization techniques with the assistance of the mobile sink.

3. It improves overall network performance by preventing congestion and reducing transmission delays.

However, introducing sink mobility also introduces new challenges. Efficient routing protocols need to be developed to handle the dynamic network topology and adapt to the changing location of the sink [13]. Strategies for sink movement, such as trajectory planning and energy-efficient movement patterns, should be considered to optimize sink mobility. Furthermore, mechanisms for sink discovery and data collection from cluster heads or designated nodes need to be designed to ensure effective communication between the mobile sink and the network [14].

In this paper, we introduce an energy-efficient routing algorithm called EPMS (Energy- aware PSO based routing algorithm with Mobile Sink support) for Wireless Sensor Networks (WSNs). It combines practical clustering and mobile sink methods to enhance the routing process. Outcomes of the proposed algorithm are listed below:

i) PSO-based Network Division: The PSO (Particle Swarm Optimization) algorithm is used to divide the network into several regions. This division helps in managing the network efficiently.

ii) Clustering Algorithm: Based on two conditions: a) distance from the region's gravity center, energy level of the node the clustering algorithm identifies suitable nodes within each region to act as cluster heads. Once the cluster head nodes are determined, the non-cluster head nodes within each cluster can route their data to their respective cluster head for aggregation and transmission to the sink or mobile sink node. This process helps reduce the communication overhead and conserve energy, ultimately extending the network's lifetime.

iii) Data Packet Formats: EPMS defines three types of data packet formats for communication within the network.

a) Hello Packet: It is beneficial for a cluster area to send and receive data.

b) Message-s Packet: It utilizes the sink node to send data.

c) Message-h Packet: It employs the information to the cluster head.

The simulation results indicate the proposed algorithm achieves several benefits which are:

i) Balanced Energy Consumption: The algorithm helps balance energy consumption across the network, preventing some nodes from depleting their energy faster than others.

ii) Prolonged Network Lifetime: By managing energy efficiently, EPMS extends the overall network lifetime, ensuring its continuous operation.

iii) Reduced Transmission Delay: The algorithm reduces transmission delay by optimizing the routing process and leveraging the mobile sink support.

The remainder of the paper is organized such as section 2 gives a brief idea about some related works followed by overall system model in section 3. Section 4 elaborates the proposed algorithm in detail followed by analysis and simulation results in section 5. Section 6 concludes the paper with future works.

2. Related Works

2.1. Sink movement-based methods

In mobile sink-based Wireless Sensor Networks (WSNs), the strategy for sink movement is determined by the requirements of the specific WSN application. One commonly used strategy is the random mobile method, where the sink node moves randomly within the network. A drawback of the random mobile strategy is that it often consumes high energy. This is because the sink node often relays its location information during its movement operation. Broadcasting location information helps other nodes in the network detect the sink's current position for significant data routing. However, persistent broadcasts can consume much of the sink node's energy resources [15]. In [16], the authors propose a random direction model for sink movement in Mobile Sink-based WSNs. This model assumes a no-memory motion mode, meaning the sink node does not consider its previous movement history or the current moving momentum and orchestration. Instead, the sink node arbitrarily visits different areas within the network. A convex optimization model inspired by support vector regression for determining an optimal trajectory of a mobile sink in Wireless Sensor Networks (WSNs) is proposed in [17]. This approach does not dependent on the determined structures like constructive grids or meeting points. It aims to improve the orientation of the mobile sink to maximize the lifetime of circumstances of applications with solitary-hop data dispatch. By formulating the problem as a convex optimization task, the authors can find an optimal sink trajectory that satisfies the given constraints and objectives. The benefits of this approach include substantially improving the network's lifetime for event-driven applications. Unique-hop data delivery refers to the straight conveyance of data from sensor nodes to the sink without intermediate relays.

2.2. Routing algorithm based on mobile sink

In wireless sensor networks, mobile sink nodes have been recognized as a way to prolong the network's lifetime. The TRAIL protocol aims to improve resource management and reduce energy expenditure in data investment. The periodic sending of HELLO packets during the movement of the mobile sink nodes consumes a significant amount of energy, which can be a drawback of the protocol [18]. In [19], the authors propose the Two-Tier Data Dissemination (TTDD) protocol, where mobile sink-based sensor network divides the whole network into an effective matrix. The network is divided into multiple grids, and the grid nodes establish the path for data transmission of the mobile sink nodes. This approach helps to mitigate the energy hole effect, where certain areas of the network experience faster energy depletion. The MSEERP (Mobile Sink architecture-based Energy Efficient Routing Protocol) algorithm utilizes grid division methods without considering the number of grids chosen. During the communication process, the nodes waste a significant amount of redundant power, which is not desirable in terms of energy efficiency [20]. In [21], the concept of fixed rendezvous points (RPs) in wireless sensor networks (WSNs) is proposed. In this approach, mobile sink nodes only visit these predetermined RPs periodically instead of moving randomly. Using fixed RPs helps expand the network's coverage area and maintain a balanced energy consumption among sensor nodes. However, one drawback of this approach is that the random movement of other nodes in the network can cause delays in network communication, as the mobile sink node needs to wait for the designated rendezvous time with the fixed RPs. The sink node follows a specific movement along with the hexagon's edges. The latter collects data from other interested events in the network using multi-hop transmission. This approach is compared to the scenario where sinks are static (not moving). The results show that the network's lifetime is significantly improved by using the sink node movement strategy along the hexagon's edge [22]. In [23], the authors propose a sink mobile method where the cluster head is selected after splitting the whole network into numerous areas. During the multi-hop communication, the mobile nodes gather data the cluster heads. However, this approach can lead to data overflow in the cluster head nodes and introduce additional communication delay. In [24], a method of track picking probability prototype is proposed by employing the Ant Colony Optimization (ACO) algorithm. This algorithm helps to upgrade the efficiency of data routing in the network. The difficulty of the proposed ACO algorithm is relatively high, which impacts its practicality. In [25], a ring-based routing protocol with a mobile sink is presented as a hierarchical routing protocol for Wireless Sensor Networks (WSNs). It utilizes an adaptive region concept, dividing the network into regions, each with a specific adaptation area. The sink node's movement is monitored, and once it moves out of the adaptive region, the location information is updated and disseminated throughout the entire network. If the sink node frequently moves out of the adaptation area, the energy consumption required to update the location information will be significant. In certain specific applications, routing protocols may require a predictable mobile strategy for the sink node. In this approach, the development path of the sink node is predetermined and known to every node in the region. This method needs to catch up in terms of scarcity of flexibility and potential energy consumption.

2.3. Routing algorithm based on PSO

The Particle Swarm Optimization (PSO) algorithm has various applications in various domains, including mechanical design, neural networks, communication, and image processing. It has also been registered to address routing problems in Wireless Sensor Networks (WSNs) to enhance network performance [26]. The PSO algorithm is inspired by the collective behavior of bird flocking or fish schooling. It involves a population of particles that search for an optimal solution by iteratively adjusting their positions and velocities in a multidimensional search space. Each particle maintains its own position, velocity along with the global best solution obtained by any particle in the swarm [27].

In the context of WSN routing, the PSO algorithm can be utilized to optimize routing decisions, such as finding the best paths or determining optimal cluster heads. By formulating the routing problem as an optimization task, the PSO algorithm explores the solution space to discover high-quality solutions that improve network performance in terms of energy efficiency, throughput, latency, or other relevant metrics. The advantage of the PSO algorithm lies in its ability to efficiently explore complex search spaces, potentially leading to improved network performance in

WSNs. However, the specific design and implementation of the PSO algorithm for WSN routing may vary depending on the specific requirements and characteristics of the network [28].

In [29], the authors introduce a modified version of the binary Particle Swarm Optimization (PSO) algorithm designed explicitly for task allocation in Wireless Sensor Networks (WSNs). Their approach is dedicated to find the optimal task allocation solution of the fitness function by considering multiple factors such as energy consumption, task execution time, and energy distribution within the network. The proposed algorithm aims to achieve the best overall performance regarding task allocation in WSNs.

To solve the sensor deployment problem, the authors in [30] propose a methodology to maximize the lifetime of heterogeneous WSNs by applying the Particle Swarm Optimization (PSO). The objective of this approach is to find the optimal locations by formulating the sensor deployment problem as an optimization task and using the PSO algorithm. The algorithm searches for the optimal node location. Once the optimal locations are computed, a heuristic algorithm is employed for scheduling the sensor nodes. Compared to a random deployment method, the proposed heuristic algorithm demonstrates improved performance in terms of network lifetime extension and energy consumption minimization. By leveraging the PSO algorithm for both sensor deployment and scheduling, the approach benefits from the optimization capabilities of PSO to find high-quality solutions [31]-[35].

3. System model

3.1Assumptions and Description of Network Design

Let's consider a sensor network$V$composed of randomly deployed sensor nodes. The nodes are static and homogeneous in nature and have same initial energy. Each sensor node can communicate with each other without any obstacle. The nodes are placed in a circular manner with a radius$X$. The network can be explained as a graph $S(V,P)$ which is undirected in nature. Here $P(i,j)$ is the wireless link between node i and node$j$. These links are symmetric and bi-directional in nature. The network is entirely divided into several equal quarters with one mobile sink. These sink nodes are free from energy constraint attribute. The transmission power can be adjusted according to the distance between the source nodes to terminal nodes in the network.

3.2 Energy Prototype

In this model we consider the total energy expenditure during the transmission process. The energy expenditure during communication process is divided into 4 types which are coined as:

i) Energy of ejection circuit (E_x)
ii) Energy utilization of amplifier (E_{mp})
iii) Energy of beneficiary circuit (E_{bf})
iv) Energy of receiver circuit (E_y)

The total energy expenditure of transmission process is the sum total of energy of amplifier and beneficiary circuit which can be explained in equation (1) below:

$$E_x(a,d) = E_{mp}(a) + E_{bf}(a,d) \qquad (1)$$

$$where, a = no. of\ data\ bits\ transmitted$$

$$d = distance\ covered\ to\ transmit\ a\ no. of\ data\ bits$$

A multipath (∇_{mp}) and a fading channel (Δ_{fc}) are designed based on the distance covered by the $a - bit\ of\ data$ from source to the destination nodes. It can be clear from the equation (2) below:

$$E_x(a,d) = \begin{cases} a \times E_{mp} + a \times \Delta_{fc} \times d^2, d < d_1 \\ a \times E_{mp} + a \times \nabla_{mp} \times d^4, d \geq d_1 \end{cases} \qquad (2)$$

$$d_1 = \sqrt{\frac{\Delta_{fc}}{\nabla_{mp}}} \qquad (3)$$

$$where, d_1 = the\ static\ value\ of\ transmission\ distance\ as\ described\ in\ equation\ (3)$$

To receive a-bit data receiving energy $E_y$is computed from the following equation (4):

$$E_y(a) = a \times E_x \qquad (4)$$

4. Analysis of Proposed Model

Our proposed algorithm is based on mobile sink which collects data from different WSNs scenarios. Experiment is done by considering the parameters such as common energy expenditure and overall network lifetime performance. The proposed model is divided into 3 parts to check the effectiveness of the method which are listed below:

i) Mobile sink node method
ii) Cluster head selection
iii) Clustering algorithm based on PSO

Let's discuss each of these methods to find out the effectiveness of the proposed algorithm.

i) Mobile sink node method

The mobile sink node method of EPMS algorithm can be described in the following steps:

Step 1: Mobile sink starts working in bi-hop manner where the cluster head broadcast a data packet notifying the sink node to visit the cluster head one after another. The unique ID code and energy of the cluster enclosed in the data packet. In a particular time-lapse, the location of the cluster head is provided to the mobile sink. The average energy for this process can be coined as E_b which is calculated from the equation (5) below:

$$E_b = \frac{\sum_{k=0}^{n-1} E_k}{n} \quad (5)$$

Where, $E_k$is the surplus energy of n no. of nodes in the network.

Step 2: The leftover energy of each node is then compared with the average surplus energy. The mobile sink selects the cluster having the maximum residual energy. Next, the data packet is released from that concerned cluster containing the cluster ID location of cluster position.

Step 3: Cluster head directly send the data packet to the mobile sink which contains the union of data and cluster position. When any mobile node regulates the data packet, it sends the packet to the cluster head.

Step 4: The data packets send the message to the cluster head which constitutes the attributes of member nodes. The data packet in the form of message contains the data information, location, residual energy of cluster.

Step 5: The cluster head communicates data to the mobile sink when the latter moves towards the former. After a certain time elapsed the mobile sink will relay the message again to move forward to the next cluster position.

ii) Cluster head selection

Cluster head collects all the information from each sensor nodes as these nodes have finite amount of energy. Then the cluster head forward the collected information. While choosing the cluster head the residual energy of the sensor nodes is taken into consideration. Selection of cluster head is done through the following steps.

Step 1: The center of gravity (P_1, Q_1) of the area is estimated based on the co-ordinates (p_i, q_i) of the region. The area of operation in the network must be executed by the minimum distance and least square of the sensor nodes which is computed in equation (6) below:

$$P_i, Q_j = \min\left(\sum_{i=1}^{n}[(p - p_i)^2 + (q - q_i)^2]\right) \quad (6)$$

Step 2: Next the distance between the center of gravity from each sensor node is calculated which is described in equation (7) below:

$$d = \sqrt{(p_1 - p_i)^2 + (q_1 - q_1)^2} \quad (7)$$

Step 3: The common leftover power of all the sensor nodes in a cluster is calculated. The sensor node is selected as a cluster head when the leftover energy of a node is higher than the common power of all the nodes in the network. Otherwise, it will search for next node for comparison.

Step 4: Next the entire cluster is visited by the mobile sink and complete one circular data transmission. The second round of data communication is essential to carry out the network energy balance. The round trip of data transmission of a speed (W) through mobile sink requires an execution time (T) which can be calculated from the equation (8) below:

$$T = \frac{\sum_{i=0}^{n-1}\sqrt{(p_{i+1}-p_i)^2+(q_{i+1}-q_i)^2}}{W} \quad (8)$$

iii) Clustering algorithm based on PSO

Suppose, we have a sensor network S which is divided into equal number of N parts. So, the average number of nodes can be denoted as $\frac{S}{N}$for each cluster inside the network. The whole network region is portioned into two equal parts according to the partition line using PSO algorithm is described in equation (9) as below:

$$S = (\alpha, \beta, \theta_\alpha, \theta_\beta) \quad (9)$$

Where, (α, β) is the horizontal and vertical co-ordinates of line segment.

θ_α is the angle between X-axis and the line segment.

θ_β is the angle between Y-axis and the line segment.

The fitness value f can be calculated as described in the equation (10) below:

$$f = x\sqrt{\sum_{n=1}^{2}(b_n - f_n)^2} + y\sqrt{\sum_{n=1}^{2}\left(\frac{E_n}{b_n} - \frac{E_t}{S}\right)^2}, (x + y = 1) \quad (10)$$

Where, $b_n(n = 1,2)$ is the count of nodes in the separated area n

E_n, E_t are the energy consumed and total energy respectively.

$$f_n = \frac{N_n}{N} \quad (11)$$

Where, N_n is the count of cluster head.

The fitness value of $n$number of nodes is computed in equation (11) above.

The PSO algorithm is described as follows:

Step 1: With position and energy details the sensor nodes in the network transmit their message to the base station.

Step 2: Then the PSO algorithm starts its execution after receiving the information and forms M number of particles. The attributes of the particle $(\alpha, \beta, \theta_\alpha, \theta_\beta)$ are generated instantly on random basis.

Step 3: The whole network is aparted into $2M$ sub-regions. The fitness value f can be calculated using the location information from equation (10).

Step 4: Fitness value f of M number of particles is calculated and it is being compared with the search results. The particle having minimum fitness value (σ_i) is treated as universal extreme value. Then, the minimum fitness value of each particle is estimated individually and the particle having least value can be treated as individual extreme value (σ_j). Thus, the updated value $(\alpha, \beta, \theta_\alpha, \theta_\beta)$ can be derived from below equations (12-15):

$$P_{pj}(t+1) = P_{pj}(t) + W_{pj}(t) \quad (12)$$

$$P_{qj}(t+1) = P_{qj}(t) + W_{qj}(t) \quad (13)$$

$$P_{\theta_\alpha j}(t+1) = P_{\theta_\alpha j}(t) + W_{\theta_\alpha j}(t) \quad (14)$$

$$P_{\theta_\beta j}(t+1) = P_{\theta_\beta j}(t) + W_{\theta_\beta j}(t) \quad (15)$$

Here, P_{pj}, P_{qj} represent the particle position and $P_{\theta_\alpha j}, P_{\theta_\beta j}$ are the angels of divided lines. The particle position and angle of division can be illustrated from below equations (16-19):

$$W_{pj}(t+1) = \delta W_{pj}(t) + p_1 \times \varphi() \times [\sigma_j(t) - P_{pj}] + q_1 \times \varphi() \times [\sigma_i(t) - P_{pj}] \quad (16)$$

$$W_{qj}(t+1) = \delta W_{qj}(t) + p_1 \times \varphi() \times [\sigma_j(t) - P_{qj}] + q_1 \times \varphi() \times [\sigma_i(t) - P_{qj}] \quad (17)$$

$$W_{\theta_\alpha j}(t+1) = \delta W_{\theta_\alpha j}(t) + p_1 \times \varphi() \times [\sigma_j(t) - P_{\theta_\alpha j}] + q_1 \times \varphi() \times [\sigma_i(t) - P_{\theta_\alpha j}] \quad (18)$$

$$W_{\theta_\alpha j}(t+1) = \delta W_{\theta_\alpha j}(t) + p_1 \times \varphi() \times [\sigma_j(t) - P_{\theta_\alpha j}] + q_1 \times \varphi() \times [\sigma_i(t) - P_{\theta_\alpha j}] \quad (19)$$

Here, δ=weight function of each particle in the cluster

φ= random value of experiment

p_1, q_1= the learning factors

t= number of repetitions

Step 5: The particles acquire a current weighted fitness value in form of updated value of $(\alpha, \beta, \theta_\alpha, \theta_\beta)$. Then it goes through an iterative process to get the minimal convergent value of f. At last, the two regions get splinted. The final cluster N is formed after the segmentation of the whole region.

5. Performance Evaluation and Simulation Results

We have validated our proposed EPMS algorithm with two existing algorithms namely LEACH (Low-energy adaptive clustering hierarchy) algorithm [36] and TTDD (Two-tier data dissemination) algorithm [15]. In our experiment, we have deployed 50 sensor nodes randomly in a circular network having area of 100×100 m^2. The initial energy of nodes is considered to be 10J. At the beginning all the sensor nodes have a fixed energy of 0.5J. The parameters of the demonstrations are described in Table 1 below:

Table 1: Experimental parameters

Key parameter	Notation	Unit of measurement
Initial Energy	E	10 J (joule)
Energy Consumption	E_{mp}	100 nJ/bit (Nano joule/bit)
Count of Nodes	N	50
Message Length	L	1000 bits
Threshold value of distance	d	$\sqrt{\frac{\Delta_{fc}}{\nabla_{mp}}}$
Free Space model of circuit	Δ_{fc}	20 nJ/bit
Multipath model of circuit	∇_{mp}	0.15 nJ/bit

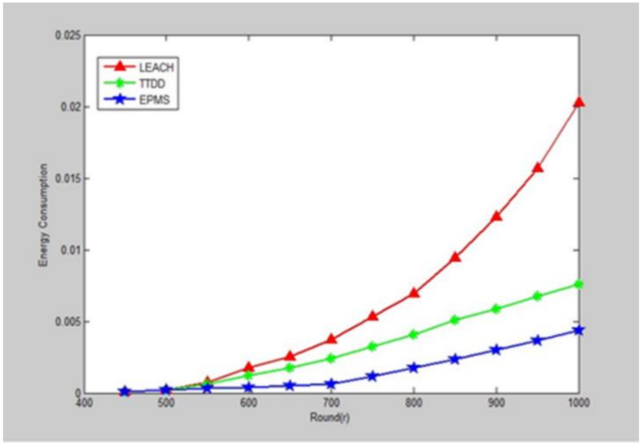

Fig 1: Comparison of energy consumption of LEACH, TTDD, & EPMS

From Fig.1, we can observe that the power utilization of the network is directly proportional to the number of rounds. With the growth in the number of the rounds, the energy usage of the sensor nodes shows an increasing trend. LEACH algorithm consumes more energy as compared to EPMS and TTDD algorithms. The latter two algorithms use mobile sink whereas the LEACH algorithm uses no such method. TTDD algorithm consumes more energy as it performs through passive round technique. The sink node utilizes energy to pass though these rounds continuously. Our algorithm is free from such method and absorbs the minimal energy associated with it.

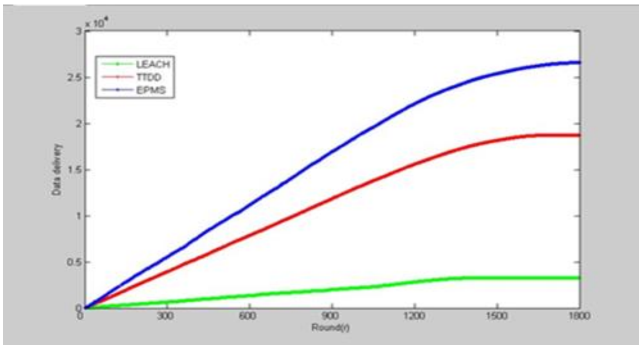

Fig 2: Comparison of data delivery of LEACH, TTDD, & EPMS

The quantity of data delivered by the sink node in LEACH algorithm is less as compared to TTDD and EPMS as LEACH uses static sink node. TTDD delivers 2.5 times less data as compared to EPMS for 1000 number of rounds as the former uses a virtual grid scenario of network. EPMS dispatches 5.5 times packets as compared to LEACH for 1000 rounds. In this manner, EPMS consumes a small amount of energy as compared to other two algorithms as shown in figure 2.

6. Conclusion and Future Work

This paper presents the EPMS (Energy-aware Particle Swarm Optimization with Mobile Sink) algorithm, a novel approach that addresses the hot spot problem in Wireless Sensor Networks (WSNs). By integrating the virtual clustering technique with the Particle Swarm Optimization (PSO) algorithm and utilizing mobile sink nodes, the EPMS algorithm significantly improves network performance, energy efficiency, and sustainability. The EPMS algorithm selects cluster heads based on parameters such as residual energy and node position, enabling efficient data collection from sensor nodes. Extensive simulations compared the EPMS algorithm with two traditional routing algorithms commonly used in WSNs. The outcomes exhibit that the EPMS algorithm outperforms these traditional algorithms regarding energy consumption, network lifetime extension, and reduced transmission delays. This research advances clustering techniques in WSNs and lays the foundation for further investigations. Future work will involve evaluating the algorithm's efficiency with a broader range of parameters and comparing it with other existing clustering algorithms in WSNs. By introducing the EPMS algorithm, this paper brings forth a promising clarification to the hot spot problem in WSNs and addresses the challenges of energy depletion and bottleneck issues. Integrating the PSO technique and mobile sink nodes showcases the potential for nature-inspired algorithms to enhance network performance and sustainability in WSNs. Overall, the EPMS algorithm opens up new possibilities for improving the lifetime and efficiency of WSNs, making them more practical and reliable in various real-world applications. As technology evolves, further enhancements and refinements to the EPMS algorithm can contribute to even more robust and efficient wireless sensor networks.

Author contributions

Lucy Dash1: Abstract, Introduction, Performance evaluation & Simulation result **Binod Kumar2 Pattanayak2:** Analysis of proposed algorithm & network modelling, Abstract **Suprava Ranjan3 Laha3:** Grammar & Proofreading, Formatting, Similarity check, References **Saumendra4 Pattnaik4:** Related Work, Conclusion, Abstract.

Conflicts of interest

The authors declare no conflicts of interest.

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