

Maximizing wireless sensor network lifetime through energy-efficient routing

Prashanth Malligere Vishweshwaraiah¹, Prema Nisana Siddegowda¹, Shivashankar Rudraswamy²

¹Department of Information Science and Engineering, Vidyavardhaka College of Engineering, Mysuru, India

²Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysuru, India

Article Info

Article history:

Received Mar 25, 2023

Revised Jun 2, 2023

Accepted Jun 3, 2023

Keywords:

Agriculture

Communication overhead

Network lifetime

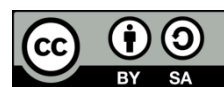
Routing overhead

Wireless sensor network

ABSTRACT

Wireless sensor networks (WSNs) are an emerging technology that has the potential to transform the way agricultural farms operate. However, deploying WSNs in agricultural farms presents a unique set of challenges. Limited coverage area, power source availability, data collection and processing, environmental factors, cost, and integration with existing systems are some of the potential problems that need to be addressed when deploying WSNs in agricultural farms. Hence, in this work, we have proposed a method for increasing the lifetime of the sensor network which will help also help to reduce the energy. The proposed method has been evaluated in terms of network lifetime of the sensor nodes, routing and communication overhead. The results have been compared with the existing M-LEACH method and the results show that there is an enhancement of 79.02% for average network lifetime. The results also show that the proposed method reduces the average routing and communication overhead by 49.17% and 38.37% respectively.

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



Corresponding Author:

Prashanth Malligere Vishweshwaraiah

Department of Information Science and Engineering, Vidyavardhaka College of Engineering

Mysuru, Karnataka, India

Email: mvprashanthresearch@gmail.com

1. INTRODUCTION

Wireless sensor networks (WSNs) are an emerging technology that allows the collection and transmission of data from a large number of remote sensors to a central location for analysis [1]. These networks are made up of small [2], low-cost devices [3] called wireless sensors that can be deployed in various environments [4], such as agriculture fields [5], to collect data on various parameters such as temperature [6], humidity [7], soil moisture [8], and light intensity [9]. In the agriculture field, WSNs have the potential to revolutionize the way farms operate by providing real-time data on crop growth and environmental conditions [10]. By using wireless sensors to monitor soil moisture levels, temperature, and other factors, farmers can optimize irrigation [11] and fertilization schedules [12], detect pest infestations [13], and improve crop yield [14]. WSNs can also help farmers save time and money by reducing the need for manual data collection and analysis [15]. With wireless sensors deployed throughout the farm, data can be collected and transmitted automatically, eliminating the need for farmers to physically monitor every aspect of their crops [16].

Moreover, WSNs can provide farmers with early warning systems for environmental risks, such as frost or drought, which can help them make informed decisions about when to plant and harvest crops [17]. This information can also be used to predict weather patterns and inform crop management strategies. Moreover, the agricultural farms often rely on accurate and up-to-date data about crop growth, soil moisture, temperature, and other environmental factors to optimize their operations and maximize crop yield. WSNs can be deployed throughout the farm to collect and transmit this data to a central location for analysis [18]. One

potential issue with WSNs in agricultural farms is that the sensors are often stationary, which means they can only collect data from a specific location. This can limit the accuracy of the data and make it difficult to detect changes in environmental conditions across different areas of the farm. However, if the sensors are mobile, they can be moved to different areas of the farm to collect more accurate and diverse data. Hence, from this the significance of the proposed method is as follows

- Present a method which increases the network lifetime of the sensor nodes for accurate data collection.
- Present a method which will reduce the energy consumption of the sensor nodes.
- Present a method which reduces the routing and communication overhead.

2. LITERATURE SURVEY

In this section, a survey has been done on the various methodologies used for wireless sensor network. Ababneh and Al-Karaki [19], they have done a survey on various issues related with the network lifetime by using various metrics and routing protocols. In this work they have evaluated the network lifetime and energy consumption of the various models by using the SENSORIA simulator. They have finally concluded by selecting an optimal routing method the network lifetime can be increased and the consumption of energy can be reduced. Khediri *et al.* [20], they have proposed a multiple-weight low-energy adaptive-clustering-hierarchy (MW-LEACH) method. In this method, they have selected the optimal cluster-heads having less residual energy by considering the distance between the cluster-heads for reducing the energy consumption, latency and increasing the network lifetime, packet delivery and throughput. The results have been compared and it shows that the MW-LEACH performs better when compared with the existing methods. Kulkarni and Jesudason [21], they have proposed an exponential cat-swarm optimization (ECSO) algorithm which will help for the multi-path transmission of data in the WSNs. In the initial stage of this algorithm, they have used a PFuzzyACO and PeSOA. Further, they have selected the best path for the transmission of the data from the source node to the destination node. The results show that the proposed algorithm reduces energy by 29.87% and the network lifetime has been increased by 18.75% when compared to other current state of art methods such as PeSOA, Fuzzy ACO and LEACH.

Maheshwari *et al.* [22], they have proposed a butterfly-optimization (BO) algorithm for selecting the best cluster heads for providing the best routing path. For doing this they have proposed an optimized cluster head selection method where they select a node on the basis of the residual energy, distance among the nodes, distance from the base station, degree of the node and centrality of the node. They have used ant-colony optimization (ACO) method for identifying the route between the cluster-heads and the base-station. They results show better performance for energy consumption, dead nodes, packet transmission and alive nodes in comparison to the existing methods. Wang *et al.* [23], they have proposed a method called trajectory-scheduling-method based on coverage-rate for multiple-mobile-sinks (TSCR-M) which uses an enhanced particle-swarm optimization (PSO) algorithm and genetic-algorithm (GA) for scheduling the various mobile sinks. The simulations show that the proposed TSCR-M performs better in comparison to the existing methods. Salman and Farzinvasht [24], they have proposed an algorithm for reducing the energy consumption when collecting data from the various sensor nodes. They have proposed a security method also in this work for providing security when collecting the data from various sensor nodes. The results show that the proposed method attains better performance in terms of energy efficiency and reliability in comparison to the existing methods. Gamal *et al.* [25], they have proposed a fuzzy-logic-LEACH (FL-LEACH) for increasing the network lifetime and transmission of the packets in the WSN. In this method, they have used K-means clustering and enhanced PSO method for forming the clusters in the WSN. The results show that the proposed FL-LEACH enhanced the network lifetime by 46% when compared with the standard LEACH and optimized fuzzy C-means (FCM).

3. ENHANCING THE LIFESPAN OF WIRELESS SENSOR NETWORKS WITH AN ENERGY-EFFICIENT APPROACH FOR AGRICULTURAL FARMS

In this section, an energy-efficient route optimizing method for reducing the energy consumption in the sensor devices as well as to increase the lifetime of the sensor network has been presented. In this section, first a system architecture has been presented for the heterogenous WSNs. Further, in this section, the complete network, channel as well as the transmission optimized method has been proposed for reducing the energy consumption of the sensor device. Finally, a rendezvous point-selection optimization method has been presented for increasing the lifetime of the sensor network.

3.1. System architecture

In this section, the system architecture of the proposed method has been given. The architecture of the proposed approach has been given in Figure 1. In the Figure 1, it is considered that the car which has various

sensors can be driven around the farm. The sensors are connected to a wireless network that transmits data to a central server for analysis. The car is driven along predefined routes to collect data on different environmental factors such as temperature, humidity, soil moisture, and sunlight. Further, it can be observed in Figure 1 that certain rendezvous points which are located closer towards the base-station seems to have a lower number of rendezvous members, and thus this is referred as Level 1. On the other hand, the rendezvous points which are located a bit further away from its rendezvous node have a higher count of rendezvous members, and thus this is referred as Level 2. As a result, the rendezvous points which are far could have higher densities of the rendezvous members or sensor devices. Using this deployment strategy, it helps to reduce the consumption of energy that the rendezvous-node needs to function. In particular, the rendezvous-node that is placed near to the car. Hence, this helps in increasing the amount of time that sensors can cover and their lifetime.

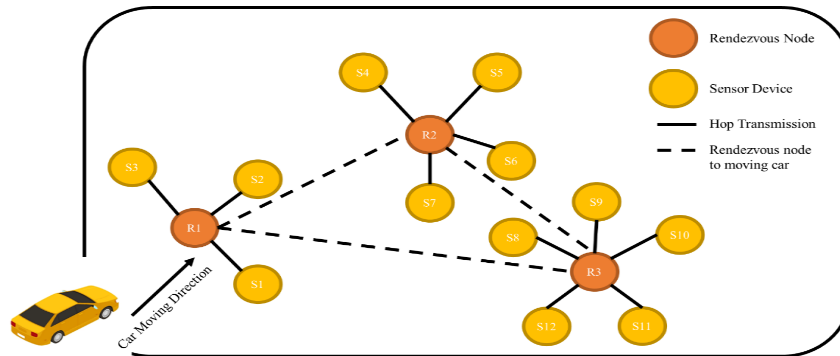


Figure 1. Architecture of the proposed approach

3.2. System, channel, transmission optimization method

In this section the system, channel and transmission optimization method has been discussed. In this proposed system, we have considered a heterogeneous wireless-sensor network. Consider two classes for different kinds of sensor devices. Let the two classes be defined as class A and class B. Assume that the class A is used for representing various sensor devices which are used for performing the different tasks like sensing. The class A is assumed to have sensors which are small, inexpensive, and widely dispersed. The sensors of the class A have been clustered to provide rendezvous points. Further, it is assumed that the sensor devices of the class B have more computational capability and are more robust in comparison to the sensor devices of class A when used in rendezvous node scenarios. Moreover, the sensor devices of the class B gather and combine sensory input from their members before sending it on to the base station/car through a network of intermediate rendezvous-node devices.

Further, assume two nodes N and O , which are deployed randomly inside a network and the placement is known by the nodes. It is assumed that every sensor device is associated/connected to one of the rendezvous-node devices according to the proposed architecture and produces mean-packet load of α bits/sec and sends the data towards the rendezvous-node. This sent data is further routed towards the base station/car. The $(M + 1)^{th}$ rendezvous-node is taken into account in this proposed work, either explicitly or indirectly using intermediate rendezvous-node devices. The proposed work also takes into account the fact that the energy used by the rendezvous-node is significantly more than that of the sensor devices. Moreover, it is assumed that the relay-node operates continuously and is active despite the fact that the member devices remain in an inactive state. As a consequence of this, the goal of this proposed work was to reduce the consumption of energy that the rendezvous-node devices consumed. This is done because it helps to increase the network coverage of the sensor device, which in turn extends the life of wireless sensor networks. This work takes into account the Rayleigh-fading method for characterizing the channel between the rendezvous-nodes as well as between base station and rendezvous-nodes. Hence, from this the gain from the channel γ between the sender as well as the receiver for the communication can be attained using the given as shown in (1):

$$i(\gamma) = M(e_0) \left(\frac{\gamma}{e_0} \right)^{-\alpha} \beta \quad (1)$$

where, $M(e_0)$ is used for representing the path-loss component for the e_0 . The path-loss component $M(e_0)$ can be evaluated using the given as shown in (2):

$$M(e_0) = \frac{H_u H_s m^2}{16\pi^2 e_0^2} \tag{2}$$

where, H_u is used for defining the antenna-gain attained by the sender, H_s is used for defining the antenna-gain attained by the receiver, β is used for defining the arbitrary variable which will help for depicting the change in the fading process. This frequency's carrier wavelength is denoted using m and the path-loss exponent is defined using o . The arbitrary variable β is chosen arbitrarily and is assumed to be exponentially-distributed. Also, the signal received from the sender is also considered to be arbitrary. This means that a signal can be received perfectly by a purely probabilistic process. For getting an ideal reception, $P\{f_s \geq \delta\} \geq \gamma_m$ is used where f_s denotes the energy attained from a signal, δ denotes the pre-determined threshold energy, γ_m denotes the ideal variable for the expected link.

Consider d_j which denotes the total hop-route achieved by a given j^{th} rendezvous-node in *bit/sec* where $j = 1, \dots, O$. Hence, from this the optimal rendezvous-pointing vector can be defined as the given as shown in (3):

$$d = (d_1, \dots, d_O). \tag{3}$$

it is important to check the sensor devices connected with each rendezvous-node j . Hence, for evaluating the size of a given rendezvous-point j , the (4).

$$\frac{d_j}{\alpha}. \tag{4}$$

Consider $j \in \{1,2,3, \dots, O\}$, $k \in \{1,2,3, \dots, O + 1\}$ and $j \neq k$. Further, consider w_{jk} which denotes the routing-load for the rendezvous-node when there is a transmission from a rendezvous-node j towards the rendezvous-node k . Consider an optimized transmission matrix, S which is defined as matrix of the elements of w_{jk} , which is represented as $O * (O + 1)$ matrix where the rows and columns are defined as $j = 1, \dots, O$ and $k = 1, \dots, O + 1$. In this work it is assumed that the $w_{jj} = 0$. Further, the main aim of this proposed work is to increase the coverage time of the sensor devices and establish the optimized transmission matrix S' and the optimal rendezvous-pointing vector d' . Assume that the Q_j is the overall mean consumption of energy for the given rendezvous node j . Then the overall mean consumption of energy Q_j can be defined using the as shown in (5):

$$Q_j = f_{recv} (d_j + \sum_{1 \leq k \leq O, k \neq j} w_{kj}) + f_{trns} (\sum_{1 \leq k \leq O+1, k \neq j} w_{jk}) + \sum_{1 \leq k \leq O+1, k \neq j} w_{jk} f_{ujk}, \quad j = 1, \dots, O \tag{5}$$

where, f_{trns} is used for denoting the dissipated energy per bit in a circuit during data transmission, f_{recv} is used for denoting the energy lost by the circuit per bit when receiving the data and f_{ujk} is used for denoting the energy lost in transit from rendezvous-node j towards the rendezvous-node k . Consider the distance between the rendezvous-node j and the rendezvous-node k is defined as e_{jk} . By utilizing the (1), the energy received per bit can be defined using the (6).

$$f_{recvjk} = f_{trnsjk} M(e_0) \left(\frac{e_{jk}}{e_0}\right)^{-o} \beta. \tag{6}$$

Further, by utilizing the Rayleigh-Channel method, the ideal variable for the links can be defined using the (7):

$$\gamma_m = \mathcal{P}\{f_{recvjk} \geq \delta\} = \mathcal{P}\left\{\beta \geq \frac{\delta}{f_{trnsjk} M(e_0)} \left(\frac{e_{jk}}{e_0}\right)^o\right\} = f^{-\frac{\delta e_{jk}^o}{f_{trnsjk} M(e_0) e_0^o}} \tag{7}$$

by using the (7), the f_{trnsjk} can be defined using the given (8):

$$f_{trnsjk} = \varphi e_{jk}^o, \quad j \neq k \tag{8}$$

where, φ is used as a constant and is defined as the given (9).

$$\varphi = \frac{-\delta}{M(e_0) e_0^o \log \gamma_m} \tag{9}$$

Hence, from this the (5) can be rewritten as given (10) by considering $j = 1, \dots, O$

$$Q_j = f_{recv} (d_j + \sum_{1 \leq k \leq O, k \neq j} w_{kj}) + \sum_{1 \leq k \leq O+1, k \neq i} w_{jk} (f_{trns} + \varphi e_{jk}^o) \quad (10)$$

Consider F_j which is used for denoting the initial energy for the j^{th} rendezvous-node, where $j = 1, \dots, O$. In this proposed work, for maximizing the coverage time, we have considered it as an optimization problem and defined it using the (11).

$$\max_{\{d, S\}} \min \left\{ \frac{F_1}{Q_1}, \frac{F_2}{Q_2}, \dots, \frac{F_O}{Q_O} \right\} \quad (11)$$

Moreover, whenever the rendezvous-nodes are deployed with similar energy, this can be represented using the shown in (12):

$$P_j = P \forall j, \quad (12)$$

further, the optimization problem defined in the (11) is same to the given (13).

$$\min_{\{d, S\}} \max \{Q_1, \dots, Q_O\} \quad (13)$$

The goal of this proposed work is finding an optimal solution for the (13). The problems which may arise when finding an optimal solution are given as follows. For a given rendezvous-node j , where $j = 1, \dots, O$, the following rendezvous-routing optimization conditions must be met (14):

$$b_j d_j + \sum_{1 \leq k \leq O, k \neq j} w_{kj} = \sum_{1 \leq k \leq O, k \neq j} w_{jk} + w_{j, O+1} \quad (14)$$

where, $0 < b_j \leq 1$ is the hop-routing aggregation function performance variable. In addition, all the packets sent by the rendezvous-nodes over a specific time frame must match those sent by the sensors during a single time frame. This can be defined using the (15).

$$\sum_{j=1}^O d_j = N\alpha. \quad (15)$$

The optimization problem defined in the (13) and by using the constraints which have been defined using the (14) and (15), the given optimization problem can be converted into a linear-programming-problem (LPP) of d, S and u by providing a supplementary variable u , where $u \geq \max\{Q_1, \dots, Q_O\}$ and can be expressed using the given as shown in (16).

$$\left\{ \begin{array}{l} \min_{\{d, S, u\}} \\ \text{such that} \\ \sum_{1 \leq k \leq O, k \neq j} w_{kj} + b_j d_j - \sum_{1 \leq k \leq O, k \neq j} w_{jk} + w_{j, O+1} = 0, \quad i = 1, \dots, O \\ \sum_{j=1}^O d_j = N\alpha \\ \sum_{1 \leq k \leq O, k \neq j} w_{kj} f_{recv} + d_j f_{recv} + \sum_{1 \leq k \leq O, k \neq j} w_{jk} (f_{trns} + \varphi e_{jk}^o) \\ \quad + w_{j, O+1} (f_{trns} + \varphi e_{j, O+1}^o) - u \leq 0, \quad j = 1, \dots, O \\ w_{jk} \geq 0 \text{ and } d_j \geq 0, \quad j = 1, \dots, O; \quad k = 1, \dots, O+1 \end{array} \right. \quad (16)$$

3.3. Selecting optimal rendezvous-points

In this section, an optimal solution for the rendezvous-point selection has been given using an algorithm for the WSN. Consider the outcome of the optimal rendezvous-pointing vector be defined using $d' = (d'_1, \dots, d'_O)$. For the rendezvous node j , where $j = 1, \dots, O$, $N'_j = d'_j/\alpha$ is given to the sensor devices. Moreover, the allocation of the sensor devices is done in a sequential way. As long as the total number of sensor devices at all rendezvous-nodes does not exceed N'_j , each node j will have a corresponding sensor device assigned to it. When that number is exceeded, the next closest rendezvous-node is examined, and so on. Algorithm 1 presents the algorithm to use in order to find the best possible rendezvous-pointing.

Algorithm 1: Optimal rendezvous pointing algorithm

```

Input:  $d^{\wedge}; d^{\wedge}' = (d_{1^{\wedge}'}, \dots, d_{O^{\wedge}'})$ 
Expected outcome:  $V_1, \dots, V_O$ 
Initialize:  $V_1 = \dots = V_O = \emptyset$  (rendezvous point sets)
Start:   For j=1 to N
           For k=1 to O
             Set  $y_{jk}$  to distance among sensor device j and rendezvous node k
           End for
Iteration:  $l = \lfloor \arg \min_{k \in \{1, \dots, O\}} \{y_{jk}, k=1, \dots, O\} \rfloor$ 
           If  $d_{1^{\wedge}'} > 0$ 
              $d_{1^{\wedge}'} = d_{1^{\wedge}'} - \alpha$ 
              $V_1 = V_1 \cup \{l\}$ 
           Else
              $y_{j1} = \infty$ 
             go to iteration
           End if
           End for
End:

```

3.4. Transmission/routing optimization

In this section, the optimization of the routing of the sensor nodes towards the rendezvous node has been described. For the purpose of this work, we take into account routing with a focus on the shortest route from the root-node to the rendezvous-node to the moving car, accounting for the total number of hops to reduce the unpredictable hop count of each transmission type. Hence, in this work for providing the best quality communication, a variable γ_q has been used to provide computational probability for the positive end-to-end reception. In order for the root-reliability γ_u to be at least $\gamma_q^{\frac{1}{L}}$, it is necessary for distinct roots of L pathways to undergo varying levels of fading. Taking into account the scenario of the shortest possible hop, the data packets are directed forward towards the base-station by going through all the nearest rendezvous-nodes which are located closer towards the level j after that. In this manner, the data is sent from one level ($j = 1$) to the next before finally reaching the base-station. In this study, we take into account a rendezvous pointing-based route solution that finds an equilibrium between the energy requirements of all of the nodes in the network. Further, the communication radius for the rendezvous points can be attained using the given as shown in (17).

$$\frac{1}{2}(s_1 - s_0), \dots, \frac{1}{2}(s_L - s_{L-1}), \tag{17}$$

The is used for reducing the energy dissipation at various rendezvous nodes. For an instance, by reducing $\frac{1}{2}(s_j - s_{j-1})$, it yields in reduced rendezvous-point sizes in the j^{th} level, helping to reduce local traffic between various rendezvous-points; shorter routing distances among matching rendezvous-nodes in the ($j - 1$) level; and a higher number of rendezvous-nodes in the j^{th} level. Since this study takes into account a homogeneous, symmetrical architecture as well as packets transmission, the load from said j^{th} -level rendezvous-node would be uniformly distributed across a greater number of j^{th} -level rendezvous-nodes, hence reducing the transmission load possessed by every j^{th} -level rendezvous-node. This helps the j^{th} ring rendezvous-node use less energy. Similarly, since there is a set number of levels included in the network, decreasing the area of the j^{th} level necessitates compensating for many other rendezvous-points, i.e., the j^{th} -level rendezvous-point. Similarly, there will be a rise in the rate of energy-dissipation towards the rendezvous-nodes. Consequently, a much more controlled energy-dissipation at multiple rendezvous-nodes is reached, which helped in increasing the coverage duration of WSN, by controlling the size of the rendezvous-point at various levels. This extends the lifetime of wireless sensor networks, as shown experimentally below.

4. SIMULATION RESULT AND ANALYSIS

In this section, the performance of the presented method has been evaluated and compared with the existing method in terms of lifetime, routing and communication overhead. For the evaluation of the lifetime of the sensor node, the first-sensor device-death (FSDD), total-sensor device-death (TSDD) and loss-of-connectivity have been considered. Very less work has been done for evaluating the lifetime performance of the WSN. For the experimentation setup, we have considered the Windows 10 operating system, Intel i5 processor which has 64-bit Quad-Core, 16GB RAM and 4GB of NVIDIA CUDA enabled-dedicated GPU. For running the evaluation tests, the SENSORIA simulator [19] has been used. The proposed method has been compared with the existing M-LEACH [20] method. The M-LEACH as well as the proposed method has been modelled utilizing the dot-net framework 4.8 and has been coded in C# language. The simulation parameters for the experimentation have been given in Table 1.

Table 1. Parameters considered for simulation

Network parameter	Value
Size of the wireless network	100 m × 100 m
Sensor devices considered	500, 1000, 1500 & 2000
No. of base station	1
Starting energy of the of sensor-devices	0.1 to 0.2 Joules (j)
Range of transmission	5 m
Range of sensing	3 m
Radio energy dissipation	50 nj/bit
Length of data packets	5000 bits
Speed of transmission	100 bit/s
Bandwidth	10000 bit/s
Delay caused due to data processing	0.1 s
Idle energy-consumption (Eelec)	50 nj/bit
Energy required for amplification (Emp)	100 pJ/bit/m ²

4.1. Performance evaluation of the sensors devices network lifetime

In this section the performance evaluation for the sensors lifetime by taking into account the overall number of sensor devices death has been given in this section. For the evaluation, the sensor-devices have been varied from 500 to 2,000 and the experiments have been conducted. The performance evaluation of the sensors network lifetime has been given in Figure 2. When compared with the M-LEACH method, the results demonstrate that the proposed method enhances the lifetime of the sensor devices by 84.83%, 83.96%, 77.22%, and 70.09% for 2,000, 1,500, 1,000, and 500 sensor devices respectively. When overall sensor-device death is taken into account, the proposed method achieves a 79.02% improvement in average lifespan performance over the M-LEACH. The conclusion that can be drawn from this is that lifetime performance can be scalable to accommodate different densities of networks.

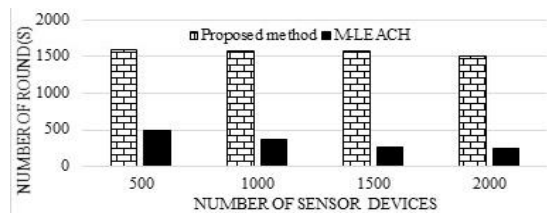


Figure 2. Performance evaluation of sensor devices network lifetime

4.2. Performance evaluation for routing and communication overhead

In this section, the performance evaluation for routing and communication overhead by varying the sensor devices has been evaluated. For the evaluation, the sensor-devices have been varied from 500 to 2,000 and the experiments have been conducted. The routing overhead has been given in the Figure 3. When compared with the M-LEACH method, the results demonstrate that the proposed method decreases the routing overhead of the sensor devices by 52.93%, 46.80%, 45.06% and 52.62% for 2,000, 1,500, 1,000, and 500 sensor devices respectively. When compared to the M-LEACH method, the proposed method reduces routing overhead by an average of 49.17%. Further, the communication overhead has been given in Figure 4. When compared with the M-LEACH method, the results demonstrate that the proposed method decreases the routing overhead of the sensor devices by 42.88%, 49.644%, 27.25% and 33.75% for 2000, 1500, 1000, and 500 sensor devices respectively. When compared to the M-LEACH method, the proposed method reduces communication overhead by an average of 38.37%.

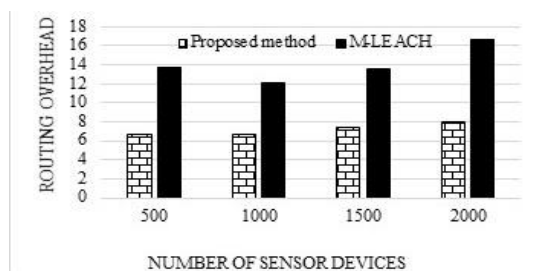


Figure 3. Performance evaluation for routing overhead

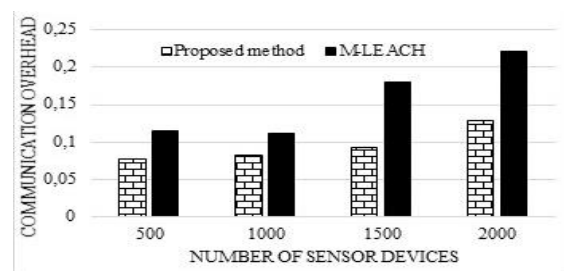


Figure 4. Performance evaluation for communication overhead

4.3. Discussion

The experimentation has been done by considering various parameters like network lifetime, routing and communication overhead which has been discussed in the previous sections. The results show that the proposed method attains better performance in comparison to the M-LEACH method. In this section, the existing methods have been compared with the proposed method for the evaluation of the sensor-devices network lifetime. Most of the existing works have considered the network lifetime of the sensor devices for the comparing it with the other existing methods. Moreover, in most of the existing works, the FSDD has been considered as the performance metric. Furthermore, the loss of connection among the sensor devices affects the overall lifetime performance of the WSN. Hence, in this work, we have considered the loss of connectivity, FSDD and TSDD for the evaluation of the lifetime of the network. In Table 2, the performance evaluation of the sensor devices network lifetime of the proposed method has been compared with the other existing methodologies. In this Table 2, the lifetime improvement attained by the existing methodologies [1]–[4] has been compared with the proposed method. From the results it can be seen that the proposed method attains superior performance in comparison to the existing methodologies. To increase the lifespan performance of WSNs, the proposed method minimizes the energy used by the rendezvous node while simultaneously increasing coverage time. As a result, it will be easier to provide the kind of energy-efficient architecture necessary for real-time application services.

Table 2. Performance evaluation of sensor devices network lifetime compared with existing methodology

Methodology	Lifetime improvement attained by the various existing method by taking into account the total sensor-device death
Kulkarni and Jesudason [21]	55.0%
Maheshwari <i>et al.</i> [22]	44.0%
Wang <i>et al.</i> [23]	36.48%
Salman and Farzinvas [24]	80.27%
Gamal <i>et al.</i> [25]	80.54%
Proposed method	81.02%

5. CONCLUSION

It is difficult to build an architecture that is both energy efficient and capable of supplying non-real-time as well as real-time services and applications in WSN. Substantial research demonstrates that several strategies have been recently offered to improve the sensor network's energy efficiency. Hence, in this work we have proposed an energy-efficient method which will increase the network lifetime of the sensor network. In order to maximize the lifetime of a sensor network while decreasing the amount of energy it consumes, it is necessary to perform routing optimization and take shortest path based routing into account. Experiments have been conducted by using the SENSORIA simulator and compared with the existing methods. The results show that the proposed method has attained an improvement of 79.02% for the network lifetime when compared with the M-LEACH method. Also, the proposed method reduces routing and communication overhead by 49.17% and 38.37% respectively. From all the results, the proposed method can be used for both the non-real-time as well as real-time services and applications in WSN.




REFERENCES

- [1] M. Majid *et al.*, "Applications of wireless sensor networks and internet of things frameworks in the industry revolution 4.0: a systematic literature review," *Sensors*, vol. 22, no. 6, p. 2087, Mar. 2022, doi: 10.3390/s22062087.
- [2] H. F. Sultan and M. N. Fadhil, "Wireless sensor networks designs and protocols: a survey," in *2022 8th International Conference on Contemporary Information Technology and Mathematics, ICCITM, 2022*, pp. 318–323, doi: 10.1109/ICCITM56309.2022.10032000.
- [3] V. K. H. Prasad and S. Periyasamy, "Energy optimization-based clustering protocols in wireless sensor networks and internet of things-survey," *International Journal of Distributed Sensor Networks*, vol. 2023, pp. 1–18, Jan. 2023, doi: 10.1155/2023/1362417.
- [4] D. Kandris, C. Nakas, D. Vomvas, and G. Koulouras, "Applications of wireless sensor networks: An up-to-date survey," *Applied System Innovation*, vol. 3, no. 1, pp. 1–24, Feb. 2020, doi: 10.3390/asi3010014.
- [5] D. Ardiansyah, A. S. M. Huda, R. G. Pratama, and A. P. Putra, "Wireless sensor network server for smart agriculture optimization," *IOP Conference Series: Materials Science and Engineering*, vol. 621, no. 1, Oct. 2019, p. 12001, doi: 10.1088/1757-899X/621/1/012001.
- [6] R. Abbasi-Kesbi, A. Nikfarjam, and M. Nemati, "Developed wireless sensor network to supervise the essential parameters in greenhouses for internet of things applications," *IET Circuits, Devices and Systems*, vol. 14, no. 8, pp. 1258–1264, Nov. 2020, doi: 10.1049/iet-cds.2020.0085.
- [7] D. K. Rathinam, D. Surendran, A. Shilpa, A. S. Grace, and J. Sherin, "Modern agriculture using wireless sensor network (WSN)," in *2019 5th International Conference on Advanced Computing and Communication Systems, ICACCS 2019*, Mar. 2019, pp. 515–519, doi: 10.1109/ICACCS.2019.8728284.
- [8] J. Lloret, S. Sendra, L. Garcia, and J. M. Jimenez, "A wireless sensor network deployment for soil moisture monitoring in precision agriculture," *Sensors*, vol. 21, no. 21, p. 7243, Oct. 2021, doi: 10.3390/s21217243.
- [9] J. Zhang and Y. Wang, "Design of remote control device using wireless sensor network and its use in intelligent monitoring of farmland information," *Eurasip Journal on Wireless Communications and Networking*, vol. 2021, no. 1, May 2021, doi: 10.1186/s13638-021-01997-1.




- [10] A. Kochhar and N. Kumar, "Wireless sensor networks for greenhouses: An end-to-end review," *Computers and Electronics in Agriculture*, vol. 163, p. 104877, Aug. 2019, doi: 10.1016/j.compag.2019.104877.
- [11] G. Santhakumar, R. Vadivelu, K. Harshini, N. G. Krishanth, and G. Haritha, "Smart irrigation system for agriculture using wireless sensor network," in *2021 7th International Conference on Advanced Computing and Communication Systems, ICACCS 2021*, Mar. 2021, pp. 711–714, doi: 10.1109/ICACCS51430.2021.9441859.
- [12] M. Skoczeń, M. Ochman, K. Spyra, M. Nikodem, D. Krata, M. Panek, and A. Pawłowski, A. "Obstacle Detection System for Agricultural Mobile Robot Application Using RGB-D Cameras," *Sensors*, vol. 21, pp. 5292, 2021, doi: 10.3390/s21165292.
- [13] J. Zhao, S. Sun, and J. Guo, "Design of intelligent monitoring system for facility agricultural environment based on wireless sensor network," *China Agricultural Machinery Chemical Report*, vol. 41, no. 4, pp. 152–157, 2020.
- [14] B. Zhang and L. Meng, "Energy efficiency analysis of wireless sensor networks in precision agriculture economy," *Scientific Programming*, vol. 2021, pp. 1–7, Aug. 2021, doi: 10.1155/2021/8346708.
- [15] A. Z. Bayih, J. Morales, Y. Assabie, and R. A. D. By, "Utilization of internet of things and wireless sensor networks for sustainable smallholder agriculture," *Sensors*, vol. 22, no. 9, p. 3273, Apr. 2022, doi: 10.3390/s22093273.
- [16] A. Triantafyllou, P. Sarigiannidis, and S. Bibi, "Precision agriculture: a remote sensing monitoring system architecture," *Information (Switzerland)*, vol. 10, no. 11, p. 348, Nov. 2019, doi: 10.3390/info10110348.
- [17] A. Villa-Henriksen, G. T. C. Edwards, L. A. Pesonen, O. Green, and C. A. G. Sørensen, "Internet of things in arable farming: implementation, applications, challenges and potential," *Biosystems Engineering*, vol. 191, pp. 60–84, 2020, doi: 10.1016/j.biosystemseng.2019.12.013.
- [18] Y. Shen, "Construction of a wireless sensing network system for leisure agriculture for cloud-based agricultural internet of things," *Journal of Sensors*, vol. 2021, pp. 1–11, Nov. 2021, doi: 10.1155/2021/3021771.
- [19] N. Ababneh and J. N. Al-Karaki, "On the lifetime analytics of IoT networks," in *Proceedings of the 2020 IEEE International Conference on Communication and Signal Processing, ICCSP 2020*, Jul. 2020, pp. 1086–1090, doi: 10.1109/ICCSP48568.2020.9182272.
- [20] S. E. Khediri, R. U. Khan, N. Nasri, and A. Kachouri, "Mw-Leach: Low energy adaptive clustering hierarchy approach for WSN," *IET Wireless Sensor Systems*, vol. 10, no. 3, pp. 126–129, Apr. 2020, doi: 10.1049/iet-wss.2019.0195.
- [21] P. K. H. Kulkarni and P. M. Jesudason, "Multipath data transmission in WSN using exponential cat swarm and fuzzy optimisation," *IET Communications*, vol. 13, no. 11, pp. 1685–1695, Jul. 2019, doi: 10.1049/iet-com.2018.5708.
- [22] P. Maheshwari, A. K. Sharma, and K. Verma, "Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization," *Ad Hoc Networks*, vol. 110, p. 102317, Jan. 2021, doi: 10.1016/j.adhoc.2020.102317.
- [23] J. Wang, Y. Gao, C. Zhou, R. S. Sherratt, and L. Wang, "Optimal coverage multi-path scheduling scheme with multiple mobile sinks for WSNs," *Computers, Materials and Continua*, vol. 62, no. 2, pp. 695–711, 2020, doi: 10.32604/cmc.2020.08674.
- [24] M. F. A. Salman and L. Farzinvas, "A hybrid algorithm for reliable and energy-efficient data gathering in wireless sensor networks," *International Journal of Communication Networks and Information Security*, vol. 11, no. 1, pp. 167–174, Apr. 2019, doi: 10.17762/ijcnis.v11i1.3663.
- [25] M. Gamal, N. E. Mekky, H. H. Soliman, and N. A. Hikal, "Enhancing the lifetime of wireless sensor networks using fuzzy logic LEACH technique-based particle swarm optimization," *IEEE Access*, vol. 10, pp. 36935–36948, 2022, doi: 10.1109/ACCESS.2022.3163254.

BIOGRAPHIES OF AUTHORS






Dr. Prashanth Malligere Vishweshwaraiah    received the B.E. degree in Information Science and Engineering and M.Tech. Degree in Computer networks in 2005 and 2013 respectively, and completed the Ph.D. degree from Visweshwaraya technological University, Karnataka. He is currently working as an Associate Professor in the Department of Information Science, VVCE, Mysuru, Karnataka. His area of specialization is artificial intelligence (AI), in designing robots. He can be contacted at email: prashanthmv009@gmail.com.



Prema Nisana Siddegowda    is the Associate Professor, Department of ISE at the VVCE, Mysuru. She has domain expertise majorly in data mining/machine learning. She has about 17 research papers published in various peer reviewed and refereed journals/Conferences. She is also a member of bodies ISTE and IETE. She can be contacted at email: prema.gowda@gmail.com.



Dr. Shivashankar Rudraswamy    is Assistant Professor in the Department of Mechanical Engineering, VVCE, Mysuru. He completed B. E. M. Tech and Ph.D. in Mechanical Engineering from VTU. He is life member of Indian Society of Technical Education (ISTE). He has published 05 papers in national and international Journals. Teaching experience 12 years. His areas of interest include composite materials, tribology. He can be contacted at email: shivashankar.r@vvce.ac.in.