An energy efficient data gathering scheme for wireless sensor networks using hybrid crow search algorithm

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Abstract
The most important challenge in Wireless Sensor Networks (WSNs) is to investigate mechanisms for energy-efficient data gathering. Within the operating range of Wireless Sensor Network (WSN), the sensor nodes are distributed to send the sensed data to the base station. During the transaction of data, some amount of energy is wasted. So, this work is focused on providing an energy-efficient data gathering scheme by Circular Clustering and Hybrid Crow Search Algorithm for enhancing the lifetime of network. Learning to maximize the lifetime of network and to attain supreme energy efficiency. In the proposed scheme, for robust data gather node selection; initially, the circular cell clusters are accomplished by separating the entire area of the sensor network. Hereafter, to select precise data gathering node in the circular cell cluster region, a multi objective based weighted sum approach is employed for proximity, communication cost, residual energy and coverage. Further, a routing and dynamic mobile sink relocation mechanism are performed to gather data form cluster head using hybrid crow search algorithm (HCSA). Based on the parameters such as total energy consumption, many alive nodes, and network lifetime, the capability of the proposed technique has been investigated. The proposed strategy has better performance analysis when contrasted to the existing techniques.

KEYWORDS
dynamic mobile sink relocation, energy efficient data gathering, hybrid crow search algorithm, weighted sum approach, wireless sensor networks

1 | INTRODUCTION

At present, WSN is considered as a dynamic element in the world and that working with the help of wireless communications, embedded computing and sensors [1]. The application of WAS is extended into various domains such as forest fire detection, target tracking, health care monitoring, landslide monitoring and automatic irrigation management [2, 3]. At starting, WSN is designed for latency-tolerant, low power, and low data rate applications. A lot of sensors nodes are available in WSNs to perform the specific task or measurement for temperature, pressure, humidity, etc. [4]. During the working of WSN, the energy consumption rates are mainly depending on the node performance and its quantity. Some limited number of nodes are enough in WSN to perform a specific task depends on the situations. Nevertheless, in WSN, plenty of unwanted sensor nodes are used along with the required nodes; this is the major limitation of WSN [5, 6].

The most required operation in wireless sensor networks operations is data gathering [7, 8]. Deduction of energy consumption happens by the usage of data gathering in the elimination of redundancy. A good approach used only limited nodes during transmission of data (information). Such kind of nodes is termed as aggregator nodes and methods are referred to as data gathering [9, 10]. In the cluster, the data of various sensor nodes are joined by the performance of simple processing redundancies are eliminated, and the data transmission is reduced before forwarding data into the sink node [11]. The data gathering process is categorized according to the characteristics like the network topology, network flow and quality of services [12].
Huge numbers of useless sensing data are generated frequently for the surveillance and reconnaissance in the WSNs applications [13, 14]. For the reduction in energy consumption, efficient data aggregation technique is used by controlling these data in the network [15]. For the aggregation of the massive range of data, several cluster methods are utilized before work which is produced from the sensors present in target tracking applications [16]. Effectiveness is shown only in restricted environments by the data aggregation algorithms, during adaptation of other situations, it possesses a great problem. A proposal of different hybrid clustering aided data aggregation methods [17] is made to overcome this problem. For target tracking applications, the data-gathering technique is necessary for detection and creation data for these targets. This will cause multiple sensors a huge amount of unnecessary, redundant data are generated. For avoiding this kind of problem efficient data aggregation is used, and for tracking the target successfully, the chance is improved.

Moreover, the complication for the sink node is to process the massive range of data produced in a large amount of sensor nodes [18]. For reducing the transmission level of aggregated data packets to the sink node by merging data into highly sensitive information at the aggregator nodes which results in the preservation of battery power and bandwidth [19]. To diminish the level of data transmission and eliminate data redundancy, data aggregation methods are developed in WSN and also to enhance the precision of the data. This strategy enhances the network management using proper sensor networking system [29, 31].

1.1 Motivation

For the good performance of bandwidth and battery utilization data gathering is preferred and also intensify the lifetime of the network, in the network communication comprises nearly 70% in the total energy consumption [20]. To mitigate the above-discussed problems, we develop an energy-efficient data aggregation [26–28] scheme that is applicable for densely distributed WSNs.

1.2 Contribution

Contribution of this work is to design an energy-efficient data gathering scheme which is developed to maximize network lifetime as well as minimize the energy consumption of distributed WSN based on the hybrid crow search algorithm. The circular cell clusters are achieved in this proposed scheme from the entire area of the sensor network region to perform the robust data gathering. Moreover, multiple circular cell clusters are considered into one cluster region, further each circular cell cluster region, the tree structure is formed among all available nodes in the circular cell cluster region for confirming that the smallest energy consumption between them for transmitting the messages.

The organization for the present paper, Section 2 contains the details regarding previous research work related to WSNs. The Architecture of the entire paper is explained in Section 3. The performance analysis and overall conclusion for the present work are explained in Sections 4 and 5 correspondingly.

2 RELATED WORKS

Tomar and Shukla [21] had performed an investigation to limit the energy consumption in WSN using Fuzzy Based Clustering and Energy efficiency gravitational Search algorithm. According to the clustering technique, the nodes are grouped. Cluster Head (CH) collects the data from non-CH members and that data forward to the base station. A FIS (Fuzzy inference system) was employed to choose an SCH (supercluster head) from overall CHs. The base station was acquired their information regarding the CHs through the SCH. According to the energy efficiency and delivery ratio, the execution of this technique was superior.

A wolf optimization algorithm was used by Nitin et al. [22] for the fuzzy methodology to decrease the energy consumption in WSN. A sensitive-threshold protocol for energy-efficient clustering was developed using the proposed algorithm. When contrasted to the competitive clustering algorithms, the capability of the proposed technique was high according to the lifetime of the system, energy consumption and stability period.

A modified clustering methodology was proposed by Radhika and Rangarajan [23] to eliminate the overheads that occurred in the exchanging of messages and clustering of nodes. Here, the member nodes, cluster head nodes, and ancillary nodes are selected as well as decide by the Energy-based parameters. For the situations, the positions of the cluster may be changed. A fuzzy inference system was employed to perform the update calculation for reclustering the node. The improvement in data transmission and clustering was attained using the proposed technique.

According to the procedure of modified invasive weed optimization, a Fuzzy modelling based energy-aware clustering technique was proposed by Sharma et al. [24] to improve the energy efficiency in WSN. The effectiveness of each node was by the fuzzy inference model. When differentiated to the QABC (Quantum Artificial Bee Colony) and ABC (Artificial Bee Colony) protocols, the proposed techniques shows good performance.

According to Fuzzy-C means, an energy-efficient clustering algorithm was built up by Shengchao and Shuguang Zhao [25] for WSN. For the density of each node, the cluster's heads are selected and defined. To convey the intracluster communication, single and multi-hub communication modes were used. When utilizing the proposed technique, the reduction in energy consumption was accomplished.

The most important challenge in WSNs is to investigate mechanisms for data aggregation. The basic operation of sensor nodes in such a network is to handover the measured (sensed) data to the BS with the available energy at each sensor, such that
the energy is utilized efficiently. Monitoring data at any portion of the region can be obtained at one time by the finest transmission and gathering of sensed data to the base station for additional processing instead of flooding those regions. They are thus increasing significant energy savings.

3 | THE PROPOSED ENERGY-EFFICIENT DATA GATHERING SCHEME

In our work energy efficient data gathering scheme is developed to maximize network lifetime as well as minimize the energy consumption of distributed WSN based on the hybrid crow search algorithm. The circular cell clusters are achieved in this proposed scheme from the entire area of the sensor network region to perform the robust data gathering. Moreover, multiple circular cell clusters are considered as one cluster region. Further, each circular cell cluster region, the tree structure \[22\] is formed among all available nodes in the circular cell cluster region for confirming that the smallest energy consumption between them for transmitting the messages. Hereafter, to select the exact data gathering node in tree-based circular cell cluster region, a multi object based weighted sum approach is considered which has been analyses four parameters such as proximity, communication cost, residual energy and coverage.

Further, the optimal location of the moving mobile sink node is determined between the sink node of mobile and root node, to reduce the distances for communication as well as provide alternate routes when route failure occurred. Eventually, the sensor node is sensing and transmitting the data to both the mobile sink node and cluster head node. The proposed scheme of topology architecture is presented in Figure 1. In addition to that data gathering node selection based on multiple objectives is given in Figure 2.

3.1 | Assumptions

Some assumptions taken in this work are listed as follow,

1. In an omnidirectional way, the node links are arranged.

2. Numerous sensors and only one base station are present in the WSN.

3. In a circular region, the nodes are appropriated arbitrarily.

4. The abilities of all sensors that exist in a particular circular region are almost the same.

5. The base station of WSN is fixed outside of the sensors conveyed territory, and it utilized a high amount of power.

6. The base station and sensors have a stationary position.

7. Before registering the sensors, an identifier ID is provided to each of them.

8. Batteries of sensors cant rechargeable after the exhaust of their energy. The sensors are useless after the drying of batteries.

9. Nodes share their information with their elected time division multiple access slots.

10. When differentiating both communication power and computation power, the range of communication power is high.

3.2 | Energy model

The energy is distributed in this work to run electronic elements of both transmitter and receiver. The energy model delivers energy (1) for conveying a \(q\)-bit message to a \(d\) (distance).

\[
E_{\text{TX}}(q, d) = \begin{cases} 
E_{\text{elec}} \times q + \varepsilon_{\text{free-space-amp}} \times q \times d^2 & \text{for } d < d_{\text{crossover}} \\
E_{\text{elec}} \times q + \varepsilon_{\text{multipath-fadin-amp}} \times q \times d^4 & \text{for } d \geq d_{\text{crossover}}
\end{cases} \tag{1}
\]

For crossover and distance, the channel propagation models are selected. When using channel propagation models like free space and multipath fading, (channel gain is the major problem in free space. Thus we need amplification parameter. Also here we just consider multipath fading when delay has happened it affects the strength of received signal) the amplification parameters such as \(\varepsilon_{\text{free-space-amp}}\) and \(\varepsilon_{\text{multipath-fadin-amp}}\) are introduced.
factor for multipath fading amplification model) are used correspondingly. Here $E_{\text{RX}}(q, d)$: required energy utilization for packet transmission at distance $d$ with bit $q$.

The energy utilized at the receiver is to get the $q$-bit message:

$$E_{\text{RX}}(q) = E_{\text{RX-elec}}(q) = E_{\text{elec}} \times q$$  \hspace{1cm} (2)

where, $E_{\text{RX}}(q)$ is the required energy utilization for the packet received with bit $q$. To run the electronic circuits of both receiver and transmitter, some amount of energy is consumed that is denoted as $E_{\text{elec}}$. Also, Equation (3) expressed the $d_{\text{cross}}$.

Selected threshold is based on the amplifier energy factors and particular scene.

$$d_{\text{cross}} = \sqrt{\frac{\varepsilon_{\text{free-space-amp}}}{\varepsilon_{\text{Multipath-fading-amp}}}}$$  \hspace{1cm} (3)

### 3.3 Divisions of the sensor network model

Through some simulations, all division’s formulas are obtained and discussed below. We can apply these formulas to any sensor network area. Here, the notations $W$ and $H$ are utilized to mention the width and height of the maximum transmission range. Similar to, the $N_L$ represents the number of the created layer.

$$N_L = \left\lfloor \sqrt{\frac{W \times H \times N}{2 \times (H + W)}} \right\rfloor + 1$$  \hspace{1cm} (4)

Here, the nodes available in the sensor network is represented by $N$. Likewise, the number of available clusters in the initial layer is denoted as $N_{C_L}$.

$$N_{C_L} = \frac{N}{\sqrt{2\pi}} \times \frac{\varepsilon_{\text{free-space-amp}}}{\varepsilon_{\text{Multipath-fading-amp}}} \times \frac{M}{d_{\text{toBS}}^2}$$  \hspace{1cm} (5)

The sensor network size and the mean square distance between all nodes and base stations are denoted using $d_{\text{toBS}}^2$ and $M$ respectively. The number of the clusters $N_{C_L}$ is expressed as:

$$N_{C_L} = N_{C_L} - 1, \hspace{1cm} 2 \leq i \leq N_L$$  \hspace{1cm} (6)

The base station performs all these divisions and gets the information regarding locations or positions of nodes. The base station sent a message consist of some attributes are (a) Node’s location, (b) Cluster ID, (c) Layer ID (d) Activation flag, and (e) Node ID. Based on these attributes, the relay nodes or cluster head and sensor nodes are selected. According to the concept of round-robin fashion, the cluster head is chosen in EA-DB-CRP, and that concept controls the energy consumption rate in all nodes. Therefore, the load is automatically balanced. In both first and second round, the first appeared node of the first node is considered as the head of the cluster. In terms of the weight formula, the nodes for each cluster are sorted by the base station.

### 3.4 Merging clusters algorithm

A cluster merging technique is conveyed for saving energy and decreasing the communication cost. The clusters are merged by this technique and that have nodes under a particular merge threshold. During the network creation, the base station is merging the cluster initially, and then the incapable cluster heads are detached. Before the detaching process, the number of nodes is examined for each cluster by member nodes. The proposed merge threshold is four. If the clusters have a low threshold when contrasted with the proposed threshold, they will be merged with the other cluster in the same layer. This merge threshold is maintained by the base station, and then it gets other responsible for functioning and detaching the clusters to create a new batch. MEGRE_MSG is sent by a detached cluster head to neighbouring clusters only if a merger needs to its cluster. TO_DO_MEGRE_MSG is transmitted by the cluster head if it needs to merge its neighbour cluster. Afterwards, according to a particular weight formula, the list of detached cluster head is updated automatically to reselect its cluster head.

### 3.5 Multi objective-based data gathering node selection

The data gathering node selection is carried out with a probabilistic approach. It selects the best node in the cluster as a data gathering node based on the multiple objectives, which includes proximity, communication cost, residual energy and coverage. Nodes in network utilize energy for processes such as data collection [30], transmission, and reception. Among all nodes, the data gathering node nodes has been utilized more energy than...
other nodes as they are responsible for activities such as transmission, reception of data from numerous sensor nodes and aggregation of collected data. So, these nodes need more energy for processing such tasks. In this situation, it needs an efficient data gathering node selection process. For that, here, a multi-objective data gathering node selection process is carried out that has been shown in Figure 4 and is described as follows:

3.5.1 Objective 1

Initially, the protocol finds the proximity of neighbour node \(N_{Pr_{ox}}\) based on their distance and it is given by,

\[
N_{Pr_{ox}} = \frac{1}{N_T} \sum_{i=1}^{N} d(n, i)
\]

The total number of SNs in the network is described as \(N_T\) and distance among the node and the neighbour is described as \(d(n, i)\). Therefore, the first objective is given as,

Minimize \(F_1 = \frac{1}{N_T} \sum_{i=1}^{N} N_{Pr_{ox}}(N_i)\)  (8)

3.5.2 Objective 2

The cost \(C_{Com}\) needed for communicating with the neighbour node is estimated by,

\[
C_{Com} = \frac{d_0^2}{d_{avg}^2}
\]

The above Equation (9) is the channel gain equation. The average distance among the node and neighbour is described as \(d_{avg}\) and \(d_0^2\) represents the distribution radius of nodes. The second objective is described as:

Minimize \(F_2 = \frac{1}{N_T} \sum_{i=1}^{N} C_{com}(N_i)\)  (10)

3.5.3 Objective 3

The residual energy of the node is estimated by,

\[
E_{Res} = E_T - (E_{Coll} + E_{Tran} + E_{Rec} + E_{Agg})
\]

The total energy of a node is described as \(E_T\), the energy utilized during the collection of data is described as \(E_{Coll}\), the energy utilized for transmitting data is described as \(E_{Tran}\), the energy utilized for receiving the data is described as \(E_{Rec}\), and the energy utilized for aggregating the data is described as \(E_{Agg}\). Also \(E_{Res}\) is the residual energy. The third objective is described as:

Maximize \(F_3 = \frac{1}{N_T} \sum_{i=1}^{N} E_{Res}(N_i)\)  (12)

3.5.4 Objective 4

The coverage of the node \(N_{Cov}\) is determined by,

\[
N_{Cov} = r(N_i)
\]

The radius covered by the node in the network is described as \(r(N_i)\). Therefore, the first objective is given as,

Maximize \(F_4 = \frac{1}{N_T} \sum_{i=1}^{N} N_{Cov}(N_i)\)  (14)

Fitness function has been in such a manner that a trade-off can be built within stated contradictory objectives. Here the multi-objective fitness function is made using weight sum approach (WSA). On every objective, the weight value \(W_i\) is multiplied in these objective values. As a final point, the different objectives are transformed as single scalar objective function by adding all the multiplied values.

Fitness = \(W_1 \times F_1 + W_2 \times F_2 + W_3 \times F_3 + W_4 \times F_4\)  (15)

i.e. Fitness = \(W_1 \times \frac{1}{N_T} \sum_{i=1}^{N} N_{Pr_{ox}}(N_i) + W_2 \times \frac{1}{N_T} \sum_{i=1}^{N} C_{com}(N_i)\)

+ \(W_3 \times \frac{1}{N_T} \sum_{i=1}^{N} E_{Res}(N_i) + W_4 \times \frac{1}{N_T} \sum_{i=1}^{N} N_{Cov}(N_i)\)  (16)
**Algorithm 1** Multi-objective based data gathering node selection algorithm

Input: Set of Sensor Nodes $S = \{s_1, s_2, \ldots, s_n\}$

Output: Selection of best sensor node as Data gathering Node

BEGIN

for $i = 1; i \leq n, i++$

WHILE (Selecting the Data Gathering Node)

FOR each cluster sensor node $s_i$ (Evaluate multiple objectives)

Calculate proximity $N_{Pr} = \frac{1}{N_T} \sum_{i=1}^{N_T} d(n, i)$

if ($N_{Pr}$ is minimum)

Select sensor node $s_i$

else

Reject sensor node $s_i$

Calculate communication cost $C_{Comm} = \frac{d^2}{Avg}$

if ($C_{Comm}$ is minimum)

Select sensor node $s_i$

else

Reject sensor node $s_i$

Calculate residual energy $E_{Res} = E_T - (E_{Coll} + E_{Trans} + E_{Rec} + E_{Agg})$

if ($E_{Res}$ is maximum)

Select sensor node $s_i$

else

Reject sensor node $s_i$

Calculate coverage $N_{Cov} = r(N)$

if ($N_{Cov}$ is maximum)

Select sensor node $s_i$

else

Reject sensor node $s_i$

Choose $s_i$ which maximizes the fitness

END FOR

END WHILE

END

We take $W_1 + W_2 + W_3 + W_4 = 1$ and $0 \leq W_i \leq 1, \forall i, 1 \leq i \leq 4$. Here, the main goal is for maximizing the value of fitness and it is given as,

$$F(X) = \text{Maximize} \{\text{Fitness}\} \quad (17)$$

The node which satisfies all of the objectives will be chosen as a data gathering node. That means node with higher energy and coverage at low cost and proximity will be selected. The selected data gathering node in every cluster is responsible for the aggregation and forwarding the packets to BS directly or through other hops. After selecting the data gathering node on every cluster, the route will be identified for transmitting the aggregated data to BS.

### 3.6 Hybrid CSA implementation for routing and sink relocation

To achieve energy-efficient route optimization based dynamic relocation a mobile sink within a circular cluster-based network infrastructure using a Hybrid Bat–Crow Search Algorithm (BCSA). First, the optimal location of the moving mobile sink node is determined between the root node and the mobile sink node, to reduce the distances for communication as well as provide alternate routes when route failure occurred.

**Step 1:** Problem initializing and parameters adjusting

It is defined as the decision variables, constraints and optimization problem. After that it is valued the adaptable parameters of CSA named as; a maximum number of iterations ($iter_{max}$), flock size ($N$), awareness probability (AP) and flight length ($f$).

**Step 2:** Position initialize and crows memory

As the members of the flock in a search space of $d$-dimensional, the $N$ crows are randomly located. The feasible solution of the problem is expressed as each crow, and the number of decision variables is denoted as $d$.

$$Crow = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1d} \\ x_{21} & x_{22} & \cdots & x_{2d} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N1} & x_{N2} & \cdots & x_{Nd} \end{bmatrix} \quad (18)$$

First, initialize each crow memory. Meanwhile, at the starting iteration, it is expected that they have concealed their foods at their original locations because the crows have no experience with that iteration.

$$Memory = \begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1d} \\ m_{21} & m_{22} & \cdots & m_{2d} \\ \vdots & \vdots & \ddots & \vdots \\ m_{N1} & m_{N2} & \cdots & m_{Nd} \end{bmatrix} \quad (19)$$

**Step 3:** Fitness function evaluation

In this step, the decision variable values are inserted into the objective function; hence the value of its position is evaluated for each crow.

**Step 4:** New position generation

Suppose the crown $i$ needs to create a new place then it produces a new situation in the exploration space. For this objective, one of the flock crows $j$ are selected randomly by this crown ($m_j$) and monitors it to determine the position of the hidden foods.
Step 5: New positions feasibility checking

For each new location, each crow’s feasibility is enhanced. The crow has updated its location when the novel location of a crow is feasible. Or else, the crow stops in the present position and doesn’t travel to the created new location.

Step 6: Evaluation of new positions fitness function

The fitness of every CH in all the paths is estimated with the fitness function. It is given as:

\[ f(CH) = \text{fitness value of CH} \]  

Here, four objectives are mainly focused on avoiding node failure and traffic. They are throughput, energy, and link quality.

- The throughput \((Th)\) of CH is estimated by,

\[ Th = \sum_{i=1}^{n} CH_i[DS_{CH_i}(Loc_{CH_i}, Loc_{BS})] \]  

In Equation (27), the maximum amount of data (bits/sec) transmitted to BS from CH is represented as: \(CH_i[DS_{CH_i}(Loc_{CH_i}, Loc_{BS})]\). The data transmission speed of CH is shown as \(DS_{CH_i}\), and the location of CH and BS is represented as \((Loc_{CH_i}, Loc_{BS})\).

- The residual energy of the node is estimated using Equation (11), the energy of CHs in the path is to be estimated instead of estimating the energy of nodes.

The fitness value of CH is estimated by:

\[ f(CH) = W_1 \times Th + W_2 \times E_{Res} \]  

Where, \(W\) indicates the weight factor and its value lies between 0 and 1.

Step 7: Memory updating

The memory of crows updated based on BAT algorithm: Here, the frequency, velocity, and solution are updated based on below formulae—assessed fitness values of all bats inspiration their actions. Bats fly through velocity \(v_t\) it is pretended through an arbitrarily predefined frequency \(f\). Lastly, they find a new position \(\text{VM}_i\) in the search space.

\[ f_i = f_{\text{min}} + (f_{\text{max}} - f_{\text{min}}) \beta \]  

\[ v'_t = v''_{t-1} + \left( f(CH)'_t - f(CH)'_{\text{best}} \right) f_t \]  

where, \(f_t\) is the frequency evaluation of the number of \(i^{th}\) bat, \(f_{\text{max}}\) and \(f_{\text{min}}\) are maximum and minimum frequency standards correspondingly, \(\beta\) is the uniform distribution drawn randomly between 0 and 1.

Step 8: Termination criterion checking

Until the \(\text{iter}_{\text{max}}\) is reached the above Steps 4–7 are repeated. In terms of the objective function esteems the finest position of memory is reported as the resolution of the optimization problem while the termination criterion is met.

4 | EXPERIMENTATION AND RESULT DISCUSSION

The proposed systems have been implemented in the MATLAB environment with the system specification.

| Processor | : Intel Core 2 Quad @ 2.5 GHz |
| RAM       | : 3GB                          |
| Operating System | : Windows 7                  |
| MATLAB Version | : R 2016a Version 16.3 |

The energy efficiency, network lifetime and QoS constraints are simulated in the MATLAB platform with the experimental parameters and the test results are furnished in the following sections.

By using various simulation experiments, the performance analysis is evaluated using Matlab. Table 1 listed the parameters of the simulation. In this simulation, the values for the parameters such as \(E_{elc}, E_{amp}, E_{fs}, d_0\) and \(d_{max}\) are considered.

4.1 | Packet delivery ratio

The reciprocal ratio of transmitted data to overall data is called the ratio of packet delivery. According to applied BFO, the ratio of packet delivery is calculated.

\[ PDR = 100 - \frac{\text{number of data_received}}{\text{number of data_transmitted}} \times 100 \]  

Figure 3 displays the evaluation of the Ratio of Packet Delivery. The number of sensor nodes is taken from 100 to 500 with an increment of 50. This simulation shows that when the number of nodes rises then the Ratio of Packet Delivery shows decreasing. By comparing the proposed system with the existing systems, it is seen by the proposed system is more efficient than
**Algorithm 2** Pseudo-code for hybrid CSA based routing and sink relocation

Input: Number of possible paths for routing to BS  
Output: Optimal routing path to BS  
BEGIN  
Initialize the CHs positions and BS position.  
Initialize CSA and BAT Algorithm parameters  
Evaluate the fitness of CHs to become a route forwarder.  
WHILE termination condition not satisfied.  
FOR each CH  
 Calculate throughput of CH\(_i\),  
if (throughput is High)  
 Select cluster head node CH\(_i\) for data forwarding  
else  
 Reject cluster head node CH\(_i\)  
if (node energy is High)  
 Select cluster head node CH\(_i\) for data forwarding  
else  
 Reject cluster head node CH\(_i\)  
END FOR  
if best path identified  
 Update the best path as data forwarding path.  
else  
 Repeat the route selection process.  
end if  
if capability of any CH is low  
 Execute sink relocation process.  
/* relocation condition checking*/  
(a) For all bottom movement:  
 \(X_i = X_{axis} + 20\)  
 \(Y_i = Y_{axis} + 0\)  
(b) For all right movement:  
 \(X_i = X_{axis} + 0\)  
 \(Y_i = Y_{axis} + 20\)  
(c) For all top movement:  
 \(X_i = X_{axis} + 20\)  
 \(Y_i = Y_{axis} + 0\)  
(d) For all left movement:  
 \(X_i = X_{axis} + 0\)  
 \(Y_i = Y_{axis} + 20\)  
 Update the new position of BS.  
end if  
END WHILE  
Return best optimal path  
END  

the existing systems using TCBDGA (Tree Circular-based data gathering algorithm), (EASR hke) Energy-aware sink relocation and Fuzzy Reinforcement learning-based energy-efficient data gathering algorithm (FR-EEDG). From Figure 7, the proposed system and the FR-EEDG system are efficient than others. The
Packet Delivery ratio of the proposed system, FR-EEDG, TCBDG, EASR are 98.4%, 97%, 95% and 93% respectively. In this context, confidence interval (CI) based results are evaluated for each mean and variance. Based on 95% of the CI the graph is plotted.

4.2 | Packet loss ratio

During the transmission and receiving of data in both the destination node and source, some amount of data is lost. Based on 100 nodes, the reciprocal ratio of received data to transmitted data is known as PLR. By using Equation (27), the packet loss ratio was calculated in WSN.

\[
PLR = (1 - PDR) \times 100 \tag{27}
\]

Figure 4 shows the evaluation of the packet loss ratio and the number of nodes. The packet loss ratio is taken from 0 to 20 with an increment of 2. This simulation shows that the proposed system has more efficiency than other systems. The proposed system has a limited loss ratio than existing systems. The rise in the number of nodes will cause a rise in the loss rate. The packet loss ratio of the proposed system, FR-EEDG, TCBDG, EASR is 6%, 8%, 12% and 15% respectively. Also, the CI of proposed work is compared with existing work.

4.2.1 | Route latency

To get responses, sometimes they are required that known as latency. A lower latency rate attains finest routing. By using Equation (28), the route latency can be calculated.

\[
Latency = \frac{\text{Response\_time}}{2} \tag{28}
\]

Figure 5, it indicates the evaluation of Latency for the number of nodes. Based on this simulation result, the proposed system has a lower latency rate than other existing systems that make high efficiency in routing. The FR-EEDG system has a latency rate near to the proposed system and the other two have a larger rate compared to the proposed system. The Latency of the proposed system, FR-EEDG, TCBDG, EASR are 2, 2.2, 2.4 and 2.6 s respectively. The confidence interval (CI) based results are evaluated for each mean and variance. The graph is plotted based on 95% of the CI.

4.3 | Route end to end delay

To attain the destination node in the same network, sometimes need to receive and transmit the data that require time termed as the end to end delay. With the help of Equation (12), the end to end delay is calculated.

\[
\text{End\_delay} = \text{Transmission delay} + \text{propagation delay} + \text{processing delay} + \text{queing delay} \tag{29}
\]

Figure 6 displays the evaluation of End to End delay. The utilized system has the lowest delay than other existing systems. In 100 node the End to End delay of the utilized system is 2.8 s, FR-EEDG system has 4Sec, TCBDG system have 5.2 and 6 s for EASR system. Considering all this, the proposed system is better than other systems. CI are evaluated for all delay parameters, and this is the value of 95% of CI.

4.4 | Route throughput

The transmission of positive data over a WSN is known as the route throughput. The data transmission rate was analysed using route throughput.

\[
\text{Throughput} = \frac{\text{receiving the success of data packets in the destination} \times \text{data size} \times 8}{\text{end to end delay}} \tag{30}
\]

Figure 7, shows the evaluation of the throughput. Considering the 100 nodes, the proposed system has high throughput than other existing systems. The increase in the number of nodes will decrease throughput. Considering the case of 500 nodes the throughput is decreased and the proposed system has high throughput. The Throughput of the proposed system, FR-EEDG, TCBDG, EASR is 0.53, 0.46, 0.41 and 0.38 Mbps respectively. We also mentioned the CI for proposed work with the existing work.
4.5 Energy consumption

The energy usage of the node is considered as a vital concern in WSN because the data transmission and network efficiency are directly affected by that. The node interference in the transmission is evolved due to the lack of efficiency. $E_{\text{con}}$ is the energy consumed. The notations $l^2$ is used to signify the distance between the cluster nodes and energy loss respectively. The node $t_{\text{amp}}l^2$ gets the data from the amplifier, where $t_{\text{amp}}$ is the energy used to transmitting data. Let $e l^2$ be the energy loss in transmitting 'm-bit' data. Then the energy is calculated by,

$$E_{\text{tx}}(m, l^2) = E_{\text{con}} \times m + t_{\text{amp}} \times m \times l^2$$

(31)

Figure 8, shows the evaluation of energy consumption. The energy consumption rate is taken from 0 to 300. The proposed system uses less energy than other existing systems. By comparing with other systems, the proposed system has a steady increase in energy consumption relative to the rise in several nodes. The proposed system uses 50 mJ of energy and the EASR system uses 150 mJ energy, which is maximum on considered among 100 nodes. On considering 500 nodes, the Energy Consumption of the proposed system, FR-EEDG, TCBDGA, EASR is 165, 180, 225 and 235 mJ respectively. In this context, confidence interval (CI) based results are evaluated for each mean and variance. Based on 95% of the CI the graph is plotted.

4.6 Network lifetime

The lifetime of the network is an essential factor in wireless sensor networks. One of the primary outcomes of this proposed system is to upsurge the durability of the network. The liveliness of the network $\tau(h)$ and aggregate criterion were defined initially. The network lifetime calculations are given below,

$$\tau(h) = \tau_{aw}(h) \Lambda \tau_{tc}(h) \Lambda \tau_{k}(h) \Lambda \tau_{aw}(h) \Lambda \tau_{ln}(h) \Lambda \tau_{k}(h) \Lambda \tau_{aw}(h) \Lambda \tau_{dc}(h)$$

(32)

Where $\tau_{aw}$ is the area coverage, $\tau_{k}$ is the target coverage, $\tau_{k}$ is the k-coverage.

In Figure 9, the simulation shows the evaluation for the lifetime of network. The major concern of a system is to improve the lifetime of the network, on comparing with the existing algorithms the proposed system has a large network lifetime than others. The EASR system has less network lifetime among these existing systems. The network lifetime will decrease by increasing the number of nodes. The Network Lifetime of the proposed system, FR-EEDG, TCBDGA, EASR are 4300, 4100, 3600, and 3400 rounds respectively. CI is evaluated for all network lifetime parameters and this is the value of 95% of CI.

5 CONCLUSION

In the proposed scheme, for robust energy-efficient data gathering node section, initially, the entire area of the sensor network region is separated in the form of circular cell clusters. Hereafter, to select the exact data gathering node in cluster region, a multiple weighted sum approach is implemented in all clusters, for data gathering node selection has been done based on four parameters such as proximity, communication cost, residual energy and coverage. Further, the routing and dynamic relocation of a mobile sink is done by the hybrid crow search algorithm. Finally, results are obtained by using the performance metrics such as total energy consumption, number of alive nodes, the lifetime of the network. When compared with the existing schemes, the performance of the proposed technique is well.
REFERENCES

1. Kulkarni, R.V., Forster, A., Venayagamoorthy, G.K.: Computational intelligence in wireless sensor networks: A survey. IEEE Commun. Surv. Tutorials 13(1), 96 (2011)
2. Ozdemir, S., Xiao, Y.: Secure data aggregation in wireless sensor networks: A comprehensive overview. Comput. Networks 53(12), 2022–2037 (2009)
3. Castelluccia, C., et al.: Efficient and provably secure aggregation of encrypted data in wireless sensor networks. ACM Trans. Networks 5(3), 20 (2009)
4. Wan, S., Zhang, Y., Chen, J.: On the construction of data aggregation tree with maximizing lifetime in large-scale wireless sensor networks. IEEE Sens. J. 16(20), 7433–7440 (2016)
5. Wu, M., Tan, L., Xiong, N.: Data prediction, compression, and recovery in clustered wireless sensor networks for environmental monitoring applications. Inf. Sci. 329, 800–818 (2016)
6. Wei, G., et al.: Prediction-based data aggregation in wireless sensor networks: Combining grey model and Kalman filter. Comput. Commun. 34(6), 793–802 (2011)
7. Yu, B., Li, J., Li, Y.: Distributed data aggregation scheduling in wireless sensor networks. In: INFOCOM IEEE, Rio de Janeiro, Brazil pp. 2159–2167 (2009)
8. Xu, X.H., et al.: A delay-efficient algorithm for data aggregation in multihop wireless sensor networks. IEEE Trans. Parallel Distrib. Syst. 22(1), 163–175 (2011)
9. Maraiya, K., Kant, K., Gupta, N.: Wireless sensor network: A review on data aggregation. Int. J. Sci. Eng. Res. 2(4), 1–6 (2011)
10. Al-Karaki, J.N., Ul-Mustafa, R., Kamal, A.E.: Data aggregation and routing in wireless sensor networks: Optimal and heuristic algorithms. Comput. Networks 53(7), 945-960 (2009)
11. Jesus, P., Baquero, C., Almeida, P.S.: A survey of distributed data aggregation algorithms. IEEE Commun. Surv. Tutorials 17(1), 381–404 (2015)
12. Pandey, V., Kaur, A., Chand, N.: A review on data aggregation techniques in wireless sensor network. J Electron. Electr. Eng. 1(2), 01–08 (2010)
13. Liu, Z., et al.: A distributed energy-efficient clustering algorithm with improved coverage in wireless sensor networks. Future Gener. Comput. Syst. 28(5), 780–790 (2012)
14. Maraiya, K., Kant, K., Gupta, N.: Application based study on wireless sensor network. Int. J. Comput. Appl. 21(8), 9–15 (2011)
15. Aslam, N., et al.: A multi-criterion optimization technique for energy efficient cluster formation in wireless sensor networks. Inf. Fusion 12(3), 202–212 (2011)
16. Jung, W.S., et al.: A hybrid approach for clustering-based data aggregation in wireless sensor networks. In: Digital Society, 2009. ICDS’09, Third International Conference on IEEE, Cancun, Mexico, pp. 112–117 (2009)
17. Jung, W.S., et al.: Efficient clustering-based data aggregation techniques for wireless sensor networks. Wireless Networks 17(5), 1387–1400 (2011)
18. Renjith, P.N., Baburaj, E.: An analysis on data aggregation in wireless sensor networks. In: Radar, Communication and Computing(ICRCC), International Conference on IEEE, Tiruvannamalai, India, pp. 62–71 (2012)
19. Mishra, S., Thakkar, H.: Features of WSN and data aggregation techniques in WSN: A survey. Int. J. Eng. Innov. Technol. 1(4), 264–273 (2012)
20. Ozdemir, S., Çam, H.: Integration of false data detection with data aggregation and confidential transmission in wireless sensor networks. IEEE/ACM Trans. Networking 18(3), 736–749 (2010)
21. Xu, X., et al.: Hierarchical data aggregation using compressive sensing (HDACS) in WSNs. ACM Trans. Sens. Netw. 11(3), 45 (2015)
22. Kuo, T.-W., Lin, K.-C., Tsai, M.-J.: On the construction of data aggregation tree with minimum energy cost in wireless sensor networks: NP-completeness and approximation algorithms. IEEE Trans. Comput. 65(10), 3109–3121 (2016)
23. Navaz, A.S.S., Nawaz, G.M.K.: Flow based layer selection algorithm for data collection in tree structure wireless sensor networks. Int. J. Appl. Eng. Res. 11(5), 3359–3363 (2016)
24. Shim, K.-A., Park, C.-M.: A secure data aggregation scheme based on appropriate cryptographic primitives in heterogeneous wireless sensor networks. IEEE Trans. Parallel Distrib. Syst. 26(8), 2128–2139 (2015)
25. Bagaa, M., et al.: Distributed low-latency data aggregation scheduling in wireless sensor networks. ACM Trans. Sens. Netw. 11(3), 49 (2015)
26. Xiang, L., et al.: Compressed data aggregation for energy efficient wireless sensor networks. In: Sensor, Mesh and Ad Hoc Communications And Networks (IEEE SECON), Salt Lake City, Utah, USA (2011)
27. Yao, Y., et al.: EDAL: An energy-efficient, delay-aware, and lifetime-balancing data collection protocol for heterogeneous wireless sensor networks. IEEE/ACM Trans. Networking 23(3), 810–823 (2015)
28. Sun, G., et al.: Energy-efficient provisioning for service function chains to support delay-sensitive applications in network function virtualization. IEEE IoT J. 7, 6116–6131 (2020)
29. Huang, M., et al.: An effective service-oriented networking management architecture for 5G-enabled internet of things. Comput. Networks 173, 107208 (2020)
30. Liu, X.Y., et al.: CDC: Compressive data collection for wireless sensor networks. IEEE/ACM Trans. Parallel Distrib. Syst. 26(8), 2188–2197 (2015)
31. Sarkar, C., et al.: VSF: An energy-efficient sensing framework using virtual sensors. IEEE Sens. J. 16(12), 5046–5059 (2016)

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