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Energy efficient congestion control scheme based on Modified Harris Hawks Optimization for heavy traffic Wireless Sensor Networks

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ABSTRACT
The performance of Wireless Sensor Networks (WSNs), a subset of Wireless Ad-hoc Networks, is significantly influenced by the application, lifetime, storage capacity, processing power, changes in topology, communication medium, and bandwidth. These restrictions call for a strong data transport control in WSNs that takes into account quality of service, energy efficiency, and congestion management. Wireless networks face a significant difficulty with congestion which impacts on the loss rate, channel quality, link utilization, the number of retransmissions, traffic flow, network lifetime, latency, energy, and throughput are all negatively impacted by congestion in WSNs. Since the routing problem has been shown to be NP-hard and it has been realized that a heuristic based method delivers better performance than their traditional counterparts, routing is one of the most popular methods for reducing the energy consumption of nodes and increasing throughput in WSNs. This research provides a Rate Aware Congestion Control (RACC), an effective congestion avoidance method that enhances network performance by applying Modified Harris Hawks Optimization (MHHO). Nodes are initially clustered using the DBSCAN clustering algorithm. When compared to existing approaches, the simulation outcomes of the developed technique indicate superior service, low delay, high energy, packet delivery ratio and increased living nodes.

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Wireless Sensor Networks (WSNs); Modified Harris Hawks Optimization (MHHO); congestion control

1. Introduction

A wireless sensor network, or WSN, is a collection of sensor nodes that are spread and arranged in a network to track various environmental or physical factors, such as pressure, vibration, motion, temperature, and sound, to gauge the state of the area or the system being tracked. WSNs collect the data needed by intelligent settings, such as industrial sites, buildings, homes, and utilities. They function as a kind of communication network with a few base stations (sinks) and a large quantity of sensor nodes placed throughout a physical space [1]. There are five different types of WSNs: multi-media WSNs, terrestrial WSNs, underground WSNs, and mobile WSNs. The development of inexpensive, small, and teeny sensor nodes, which have the highly desirable abilities to sense ambient variables and analyze received data, has a considerable impact. The SNs can be placed in both approachable and unapproachable locations to collect data for use in a wide range of applications, including battlefield, constructing inspection, target field imagination, and disaster area monitoring [1]. Application-specific factors determine whether sensor node deployment is random or predictable [2]. The sensor nodes sense the statistics or event, collect the information within a predefined infrastructure, and process the signals that are received.

Figure 1 represents the manner of a wireless sensor network. There is a decrease in quality of service (QoS) in the network as a result of congested routes. The definition of the QoS is the potential for improved performance. Network congestion results in decreased network performance, which in turn causes packet losses, increased delays, and energy loss in the SNs [3,4]. When statistics packets are transferred from SNs to sink nodes, congestion mostly happens nearby. It has a negative impact on WSN performance, that may comprise packet loss, longer delays, energy waste, and numerous other things. Unfair network resource utilization, which may occur at the node or link level, is one cause of congestion [5]. The mismanagement of traffic arrival and departure rates, as well as buffer usage, are the main causes of congestion at the node level. On the other hand, channel usage is used to detect link-level congestion. WSN network lifetime is significantly increased by the congestion control approach [6,7,14–19].

A straightforward yet superior rate aware congestion control (RACC) approach using Modified Harris Hawks optimization (MHHO) has been developed to address these problems. As the name implies, the method detects and alleviates the congestion issue by adjusting the traffic rate in line with the level of congestion [8]. The two most common methods in this field

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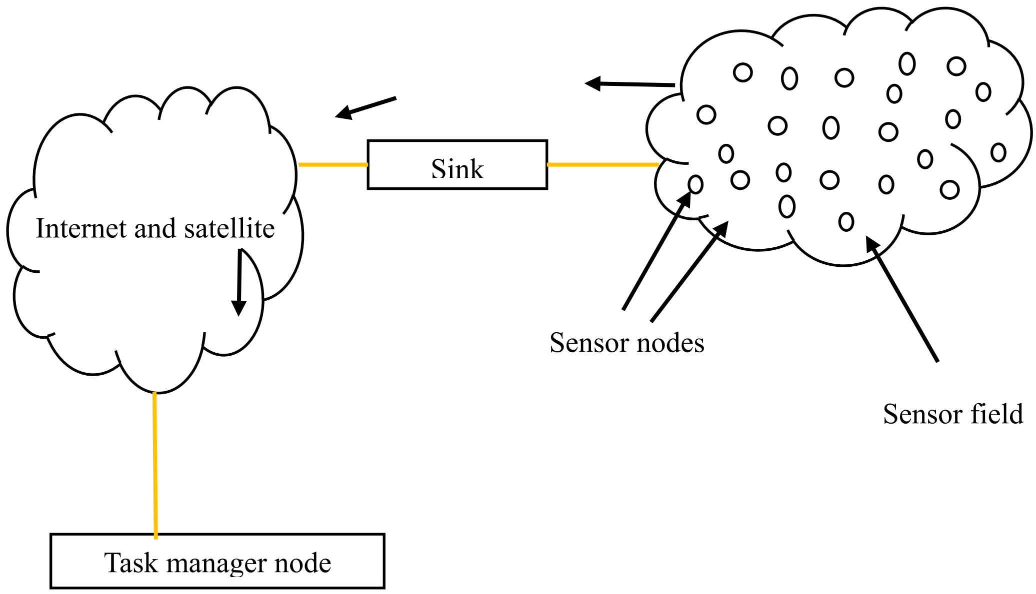

Figure 1. WSNs Architecture.

are control of traffic and resource. The resource control strategy is taken into account when the statistics flow frequency is managed, while the traffic regulated method considers the fair distribution of resources to reroute the statistics on a smaller amount busy path [9,10]. Both strategies take into account the node's priority, which is crucial in addressing congestion. We provide a method to extend the lifetime of the network, given there is no congestion, that is energy-efficient, reliable, and heuristic-based in order to meet the aforementioned difficulty. The suggested RACC technique lowers the packet rate to reduce bandwidth requirements, which requires processing fewer headers and packets and uses proportionately less energy [11]. By doing this, the network delay is reduced. Consequently, the following notable contributions to research:

- To suggest a unique RACC strategy to decrease congestion and extend the lifetime of sensor networks.
- The maximum entropy principle is used to calculate the likelihood of packet loss for each path. When taking packet loss rate into account, packet entropy aids in assessing the degree of uncertainty in congestion on alternative channels.
- Modified Every time there is an increase in congestion on the existing path, Harris Hawks optimization (MHHO) has been used to find congestion-free alternate paths and choose an ideal path to direct the load.

The remainder of the essay is organized as follows: Section 2 discusses the literature review for congestion avoidance and management. In Section 3, which also incorporates the RACC model, the suggested congestion block diagram is further developed. The proposed congestion control algorithm is described in Section 4. Section 5 explains the simulation and outcomes of the suggested mechanism (MHHO). The conclusion of the suggested method is elaborated in Section 6.

2. Related work

The literature review of various studies on congestion avoidance and congestion control algorithms is explained in this part. A fast Congestion control (FCC) method based on routing and a hybrid optimization algorithm was developed by C. J. Raman et al. in 2019 [1]. Two processing steps make up the suggested scheme. To choose the right next hop with the least amount of unwelcome queuing delay, they first developed a multi-input time on task optimization algorithm. They then proposed an improved gravitational search algorithm to create an energy-efficient route from source to end point. By improving routing to choose the optimum next node for statistics promoting, the proposed FCC system combats congestion. When considering the extremely dynamic traffic condition, P. Suman Prakash et al. (5) [5] proposed the congestion-aware load balancing technique. They recommended employing a harmony search method to construct clusters that are traffic percentage cognizant for actual load matching. Furthermore, routing and clustering have been completed by means of improved Giraffe kicking optimization. The load on the network is aggressively controlled when there are no data transmissions accessible to the owner node, and the slot is utilized. Low latency optimal link-state routing (LL-OLSR), that proactively screens the recognized route and links the source to destination with the least amount of money and energy, was planned by Suma S et al. in 2022 [6]. When a discontinuous link is found between two nodes, the LL-OLSR algorithm additionally maximizes packet delivery ratio by reducing path latency utilizing connectivity range and queuing delay, which prevents congestion. Cluster-based data fusion is the strategy that S. L. Yadav et al. (2020) [12] suggest to prevent congestion. The cluster head is chosen from among the nodes in each cluster following consideration of a number of factors, including the node's overall energy, its distance from the base station, and the likelihood of traffic in the near future. The cluster head node collects information from other cluster members, fuses it at the local level, and then sends it to the base station for final decision-level fusion. This technique enhances network connectivity, reduces traffic, and increases data reliability. For rate optimization and managing the arrival rate of data from each child node to the parent node, Karishma Singh et al. (9) [9] introduced a congestion control algorithm based on the multi-objective optimization algorithm dubbed PSOGSA. The energy of the node is taken into account via a multi-objective optimization function using the node's fitness function. As the optimization strategy controls the arrival rate based on priority, output available bandwidth, and child node energy, priority-based transmission is enabled.

Despite the fact that the aforementioned techniques can successfully address the congestion problem in WSNs, variation strategies have never been examined for any congestion-aware mechanisms. Congestion at a node can occasionally lead to a change in path, which can make it harder for a node to send a packet from source to end point if the distance grows too great. So, when the distance between SNs is too great, checking the modulation strategy aids in increasing the communication range of the packets. As a result, after thoroughly examining the aforementioned problems, a solid architecture design must be developed that not only avoids SN congestion but also enables long-distance transmission utilizing the proper modulation technique. We therefore suggested a RACC mechanism with Modified Harris Hawks Optimization (MHHO), which interconnects utilizing constant bit rate and adopts a queue administration method, taking into account all the aforementioned problems.

3. Proposed methodology of congestion control with Modified Harris Hawks Optimization

Figure 2 displays the suggested block diagram. The novel rate control-based DBSCAN Clustering with MHHO routing is the main focus of the suggested approach. It had several sources and just one washbasin. DBSCAN Clustering Algorithm is initially utilized to cluster link nodes, and each node in the cluster shares distance and energy with the other nodes in the cluster.

Retransmissions and the quantity of Residual Energy (RE) are important factors when calculating the system's performance. Monitoring packet movement in the network from various sources to sink nodes allows for the detection of network congestion. The queue length is a substantial element in this case for monitoring the congestion. The system-wide distribution of wait length is maintained throughout. Network data packets are routed using window and queue sizes. The buffer size of the receiving node is verified as each packet is sent from a source to that node; if the buffer

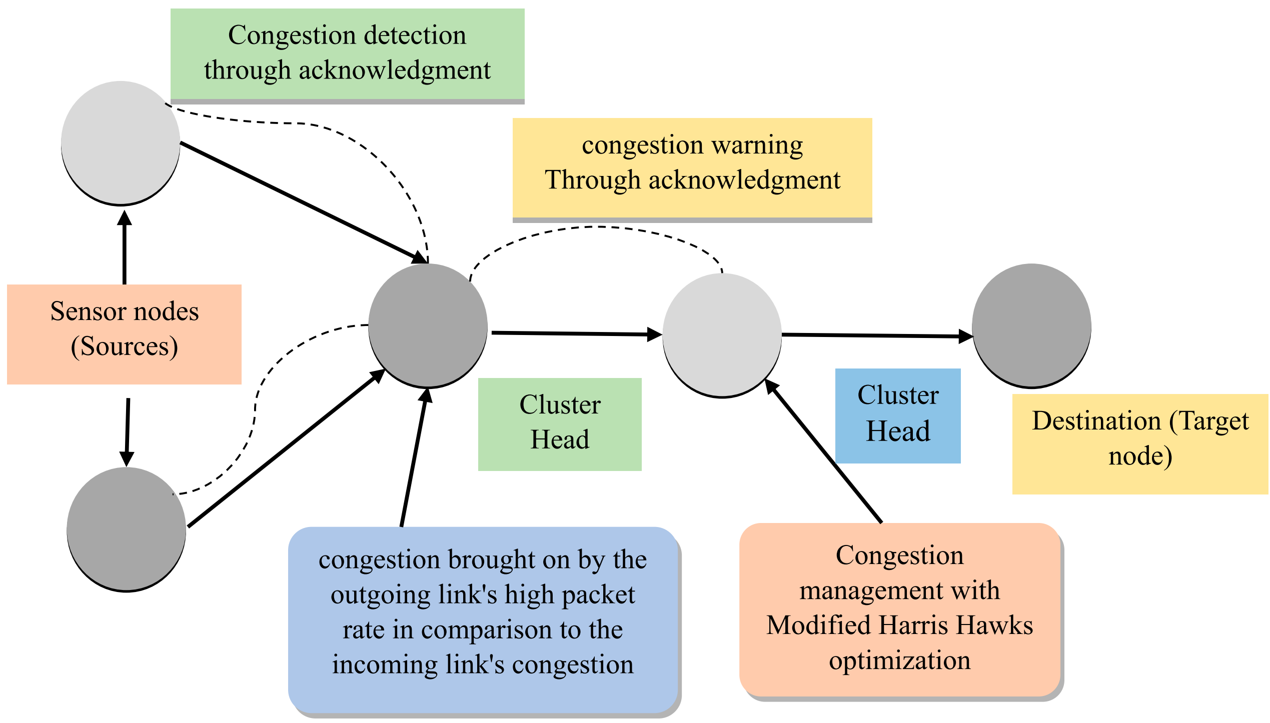

Figure 2. Proposed block diagram of congestion control with Modified Harris Hawks Optimization.

size is exceeded, either zero or no acknowledgement is sent.

The packet rate will be optimized using the Modified Harris Hawks algorithm if the acknowledgement is zero. Information is sent from one node in the cluster to another node. The routing table has to be updated using other nodes' persistent queue size values. The key idea in this case is to choose the rate in an optimized way to ensure that the receiver receives all of the data.

3.1. Rate aware congestion control mechanism (RACC)

The management/detection phase and the data rate modification phase are the two phases of the RACC mechanism that have been proposed. Below is an explanation of these two periods' specifics.

3.1.1. Detection and management phase

Figure 3 illustrates the suggested RACC model's architecture. The buffer management approach is implemented in this phase to lessen traffic congestion. The SNs typically interact with their upstream and downstream SNs. The communication from the upstream node is obtained by SN, which then forwards it to the downstream node. Congestion can be readily removed in order to keep our network from becoming congested. For the buffer management technique, congestion is expected for time "C_t" (when the number of mobile connections reaches 10). Even SN calculates the quantity of packets forwarded to its downstream SNs and the quantity of packets received from its upstream SN. For any i^{th} node, the threshold value of the buffer size (BS_i) is equal to half of the original size. Size of the initial buffer (BS_O). In the detection phase, it is determined that the congestion is at the midway level if the value of the congestion index (CI_i) at the ith node is larger than BS_i but less than BS_O.

As a result, the value of CI is decreased by 2% by lowering the traffic's date rate (DR). The phrase "intermediate load state" is used to describe this situation of congestion. On the other side, virtually little congestion is present if the traffic value is equal to BS_i. In this instance, a 1% reduction in the DR lowers the value of CI. It is recognized that this state has low congestion. On the other hand, if the value of CI exceeds BS_O, it is regarded as a frightening state also recognized as a buffer overflow. The DR is consequently decreased to 3% of its present statistics frequency. Thus, it is possible to significantly minimize or manage SN congestion in this method. When there are 15 mobile connections, congestion is predicted at time $C_t + 1$. When there are 20 connections, congestion is predicted at time $C_t + 2$, and when there are 25 connections, it is predicted at time $C_t + 3$. An index value called CI is calculated based on how many packets a buffer can hold. There is no congestion and proper traffic flow when the value of CI is smaller than BS_i (the number of mobile networks is less than 10). So, based on observations, the

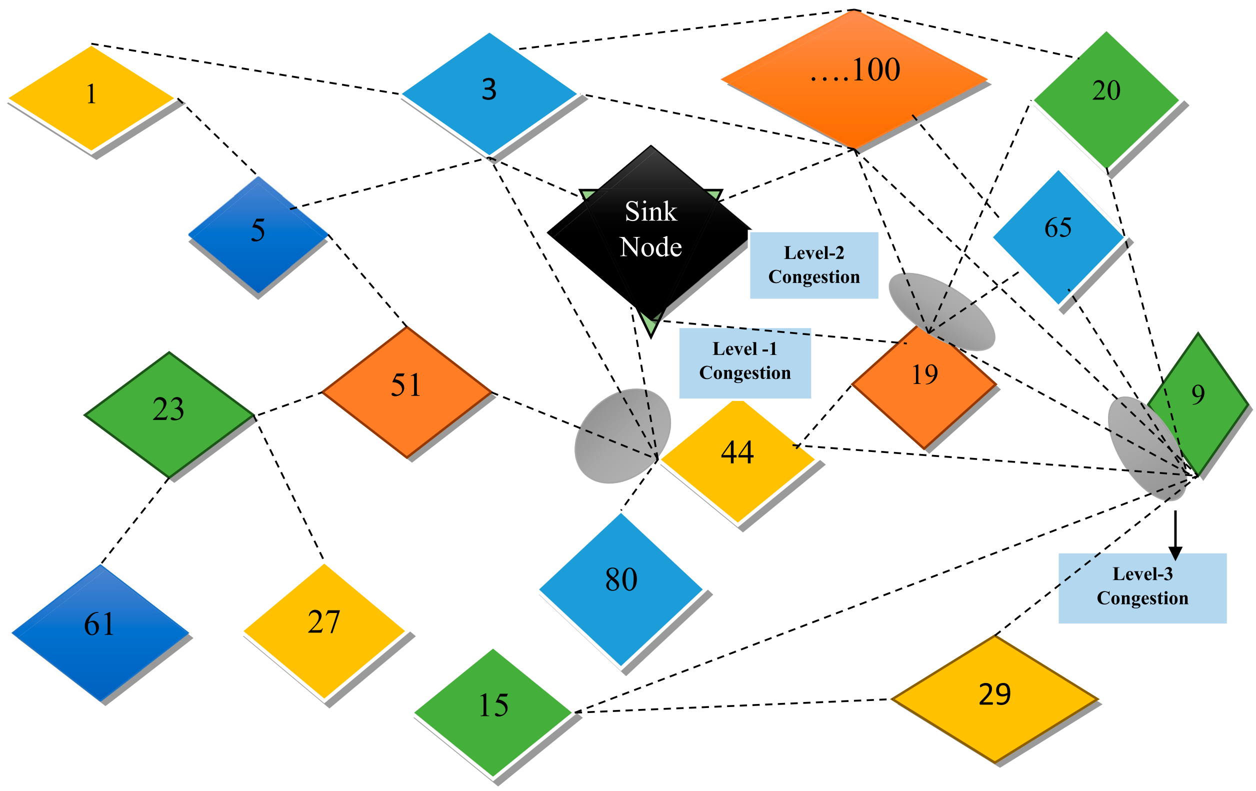

Figure 3. Architecture of proposed RACC model.

RACC mechanism is activated to reduce the congestion situation.

3.1.2. Adjusting the DR in the RACC system

Node i first determines the amount of traffic (TS_i), the amount of residualBS_i, and the amount of congestion (CL_i) at the ith node. Based on the upstream and downstream congestion, (CL_i) is updated. If all traffic flow from node m to node I is proscribed at time C_t, the CI is stated as the likelihood of congestion at node m, with n being the number of downstream nodes other than i of node m.

$$CI_i(m) \leftarrow CL_m + \sum_{i\in\{D_m-i\}} \frac{CL_i}{n} - F_{m,i} \times C_t, \forall m \in U_i \tag{1}$$

Where $F_{m,i}$ = Average forwarding speed between nodes m and i

CL_m = CL (Upstream)

CL_i = CL at the ith node

D_m = set of nodes for node m that are downstream neighbours

U_i = set of nodes for node i that are upstream neighbours

n = number of nodes that are downstream neighbours of node m.

When the numeral of influences is set to 15 during the following time interval C_{t+1},

$$CI_i(m) \leftarrow CL_m + \sum_{i\in\{D_m-i\}} \frac{CL_i}{n} - F_{m,i} \times C_{t+1}, \forall m \in U_i \tag{2}$$

Additionally, when the time windows C_{t+2} and C_{t+3} are taken into account, the CI achieved is displayed in equations (3) and (4) below.

$$CI_i(m) \leftarrow CL_m + \sum_{i\in\{D_m-i\}} \frac{CL_i}{n} - F_{m,i} \times C_{t+2}, \forall m \in U_i \tag{3}$$

$$CI_i(m) \leftarrow CL_m + \sum_{i\in\{D_m-i\}} \frac{CL_i}{n} - F_{m,i} \times C_{t+3}, \forall m \in U_i \tag{4}$$

Taking into account the first time interval

$$CI_i(m) = BS_i \tag{5}$$

A $CI_i(m)$ value less than BS_i indicates that the congestion has not occurred in the network and therefore there is no need to adjust the rate and it should automatically maintain the DR in accordance with the number of mobile connections used. Therefore, based on the observation, node m starts adjusting its DR when the value of $CI_i(m)$ crosses BS_i . This mitigates the issue of congestion of node m as much as possible in varying time (C_t, C_{t+1}, C_{t+2}, C_{t+3}). Let's assume the sum of varying time slots as "T" and each time interval as 0, 1, 2 and 3 respectively.

4. Proposed algorithm for congestion control scheme for Wireless Sensor Networks

To further explain the congestion problem and buffer occupancy behaviour, the congestion control strategies are described in this section. The data flow needs to be shifted to a different path in order to control drop rate. There must be no traffic on this alternative path. Therefore, the Modified Harris Hawks Optimization approach is employed to select an alternative congested-free route. MHHO assists in both the identification of numerous distinct congested-free paths and the selection of the best path from among many possible alternatives. The suggested strategy is preemptive, which watches an event's development before it occurs and prevents its initiation.

4.1. Clustering algorithm

Packets can be sent between cluster heads and nodes as part of transmission. To do that, we present the DBSCAN node clustering algorithm. To determine the distance between each node, this approach first determines the centroid point and estimates the Minkowski distance. Cluster will result from that. It is possible to obtain the tuned node parameter as,

$$X_{new} = \frac{x-\mu}{\sigma} \tag{6}$$

where the calculation of the mean and standard deviation is shown by Equation (7), where the mean value is μ and the standard deviation is σ :

$$\mu = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{7}$$

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N}} \tag{8}$$

where x_i describes a variable in a module's directory. N nodes make up the network's collection of nodes. Fraction mounting uses the following equation to normalize,

$$X_{new} = \frac{x}{10^j} \tag{9}$$

where j is the bare minimum of clusters. The following Equation (10), designs the initial centroid.

$$v_i = \frac{1}{C_i}\sum_{j=1}^{C_i} x_i \tag{10}$$

Where C_i is attributes to ensure proper cluster dispersion and x_i represents a variable at a node's index. The cluster will be created using the Minkowski distance as a basis. Equation (11)'s objective function is given a

$$d^{MKD}(i,j) = \sqrt{\sum_{k=0}^{n-1} |y_i - y_j|^{\lambda}} \qquad (11)$$

This distance and the centroid are used to build the cluster, and the DBSCAN Clustering algorithm is utilized to select the head of the cluster.

4.2. Modified Harris Hawks Optimization for congestion control

The new algorithm MHHO was inspired by nature. The way that Harris's hawk hunts served as inspiration for the MHHO. When prey is nearby, these birds perch in the air, scan it, and then pounce on it in a synchronized attack. In MHHO, hawks' perching behaviour is represented by the scouting phase, whilst their foraging behaviour is represented by the exploiting phase. This section presents the MHHO algorithm's mathematical model. The best solution in MHHO is referred to as the prey (x_{prey}), whereas a candidate solution is referred to as a hawk (x).

4.2.1. Exploration phase

To discover the best generally applicable solution, optimization approaches necessitate a detailed investigation of the problem landscape. In order to locate the ideal location in the search space between hills and valleys, the metaheuristic algorithm starts the search during the exploration phase. At this point, the most isolated areas are subjected to a thorough search. Equation (12) is used by HHO to randomly distribute N search agents (hawks) around the search space at random locations, $x_n^0 = \{1, 2, \ldots\ldots, N\}$

$$x_n^0 = lb_n + r_1 \times (ub_n - lb_n), r_1 = rand(a) \qquad (12)$$

The exploration phase begins once the population is initialized and lasts until the prey's escape energy, $|E| \geq 1$, is achieved. At this time, the value of E is computed as shown in equation (13):

$$E = 2E_0 \left(1 - \frac{t}{N}\right), t = \{1, 2, \ldots\ldots, N\} \qquad (13)$$

The beginning energy of the prey is E_0, and the maximum number of iterations is N. A random variable, q, which may be determined as follows (14)–(15), controls this phenomenon:

$$x_{new} = \begin{cases} x_{rand} - r_2|x_{rand} - 2r_2x_n|, q \geq 0.5 \\ (x_{prey} - x_m) - r_3[lb_n + r_4(ub_n - lb_n)], q < 0.5 \end{cases} \qquad (14)$$

Where

$$x_m = \frac{1}{N}\sum_{n=1}^{N} x_n \qquad (15)$$

where $x_m, x_{new}, and\ x_{rand}$ represent the population's dimension-wise average, the new position, and a randomly chosen position, correspondingly.

4.2.2. Exploitation phase

Exploitation is the process of several candidate solutions converging at previously recognized, high-poten tial areas of the search field. After a few cycles, this phase is activated to investigate the problem landscape. After the search agents' combined experience has identified a suitable neighbourhood, techniques are designed to encourage candidate solutions to gradually include data from the best, most distinctive global solution. However, it is crucial to keep in mind that approaching local regions too soon can cause premature convergence, which results in less-than-ideal solutions. In order to solve this issue, MHHO uses a variety of exploitation techniques targeted at specific eagle-hunting circumstances.

Algorithm 1: Modified Harris Hawks Optimization for Congestion Control

Input: No. of nodes (N), buffer length Q_{length}, Congestion status C_i
Output: Update pheromone, iteration
Begin
Suppose there are initially n nodes $N = \{N_1, N_2, \ldots\ldots N_n\}$
// First search DBSCAM Clustering search
Estimate $d^{MKD}(i,j)$, for finding number of clusters
If heuristic $h(v) < h(v)_{Min}$
CH $\leftarrow$ 0, local TRY $\leftarrow$ 0
Else
Initial condition $\rightarrow$Net condition
End if
// MHHO routing
At each path, modify the pheromone level $\tau_{ij} \leftarrow (1-\delta)\tau_{ij}$
Regarding each output queue
Local congestion status $C_i = 0$
End for
If *shared buffer*$Q_{length} \geq Global_{Threshold}$
Node iterates to sources after sending Node N-1 a Negative ACK.
For all output queues
If *shared buffer*$Q_{length} \leq Global_{Threshold}$
Local congestion status $C_i = 1$
Else
Utilise MHHO optimization to increase the data rate.
Node iterates the feedback to source nodes and sends Negative ACK to node N-1.
End if
End for
End if
If $(N)_{pheromone} > (N+1)_{pheromone}$
Upgrade the iteration
Else
Terminate the iteration
End if
End

5. Results and discussion

In this section, we put the suggested algorithm through a thorough simulation using the MATLAB simulator.

Table 1. Parameters for the proposed system's simulation.

Constraints	Value
Network Area	$10 \times 100\, m^2$
Number of nodes	20–100
Regulating the size of the packet	100 bits
Information communication rate (λ_D)	512 Kbs/s
Rate of data arrival (λ_A)	700 Kbs/s
Range of communication	20 m
Max packet in buffer (BO_{Max})	40
Congestion limit of the buffer (thr_{Max})	33
Link's pheromone density (A_{ij})	20
Evaporation factor (Ev)	0.65
Antenna type	Omni antenna
E_{amp}	$0.0013 pJ/bit/m^4$
E_{elec}	50Nj/bit
E_i	0.5J
D_{pkt}	500 bits
d_{ij}	[5,20]

The sensor nodes are randomly positioned throughout the wireless network's 2D region of 100 by 100 metres, ranging in number from 20 to 100. A base station with the ability to gather data and execute queries is located inside the network at (40, 72). $E_i = 0{:}5$ joules makes up the node's initial energy. While the amount of search rabbit is set at 6, and their maximum lifespan is 20, the pheromone generated by rabbits evaporates once every 4 s. 1500 is the maximum number of rounds or iterations. Table 1 shows the simulation parameters for the proposed system.

According to the average hop-by-hop delay, average throughput, packet delivery ratio, and node death percentage, the suggested algorithm's performance is assessed. These parameters provide the ratio of the number of packets effectively established by the receiver to the quantity of packets sent from the source, the time delay between the current hop and the next forward hop, and the rate of successful data delivery across the total bandwidth. Additionally, a comparison of the MHHO and a cutting-edge algorithm is assessed.

5.1. *Average energy usage across rounds*

Figure 4 compares the energy usage of the proposed MHHO algorithm with cutting-edge methods across the number of rounds. The results show that for the preliminary phase of rounds at 600, MHHO (Modified Harris Hawks Optimization), MO-AOA (Multi Objective Archimedes Optimization Algorithm) [13] (a nature-inspired algorithm), and CODA (Congestion Avoidance Algorithm), respectively, consume 0.14, 0.3, and 0.61 joules of energy. Additionally, as the rounds are increased up to 1500 rounds, the MHHO only uses 1.4 joules, the MO-AOA uses 1.6 joules, and the CODA uses around 1.9 joules.

This is due to the fact that the suggested algorithm selected the next hop routing path based upon higher Residual Energy (RE) and less congested routing density based on MHHO, in opposition to MO-AOA, which uses adaptive search rate modification to select

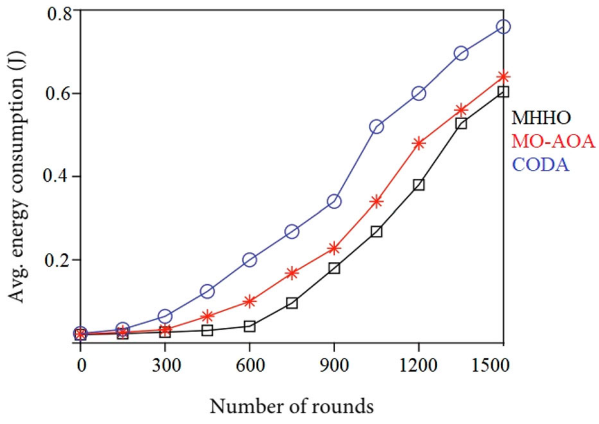

Figure 4. Average energy consumption.

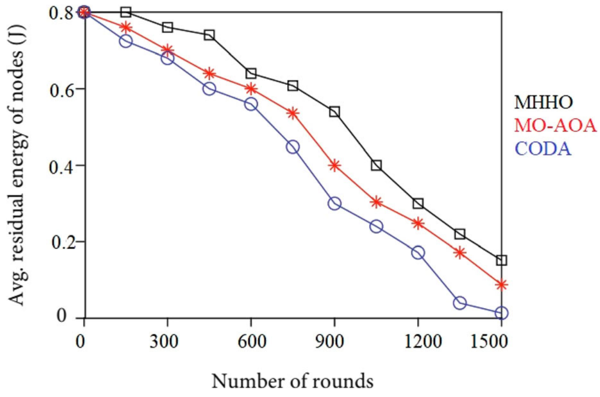

Figure 5. Average Residual energy.

the next hop and outperforms CODA method. Additionally, it is observed that the lack of a nature-inspired algorithm results in the worst performance because there are no next hop routing selection criteria.

Figure 5 shows the average RE between the MHHO and the cutting-edge algorithm. The results show that residual energy for all three algorithms reduces as the number of rounds grows, with MHHO and MO-AOA having RE of 0.5 and 0.3 joules, correspondingly, for 1500 rounds. It is also important to note that the CODA algorithm performs poorly because the choice of the next route based on the shortest distance and does not take into consideration the RE of the subsequent hop. This results in an increase in total energy consumption and a reduction in the system's lifetime.

Figures 6 provide a comparison of the proposed algorithm's average throughput employing 40 nodes in the network. Figure 6's results make it abundantly evident that the suggested algorithm, MHHO, enhances throughput by 38% when compared to MO-AOA and by 41% when compared to CODA algorithm, respectively.

Figures 7 compare the average hop-by-hop latency between the state-of-the-art algorithm and the proposed algorithm ECA-HA. This measure is crucial for displaying the mechanism used to control inter-path interference, overhead caused by the conversation of

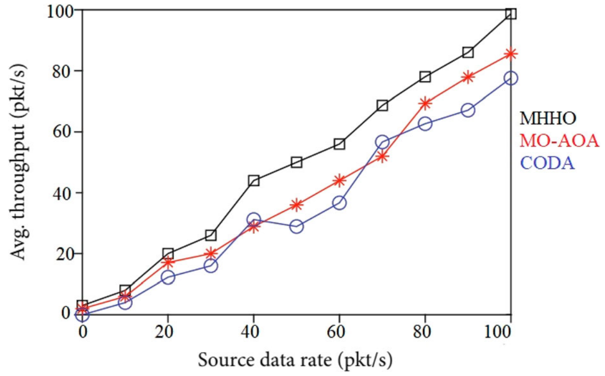

Figure 6. Average throughput of the proposed algorithm.

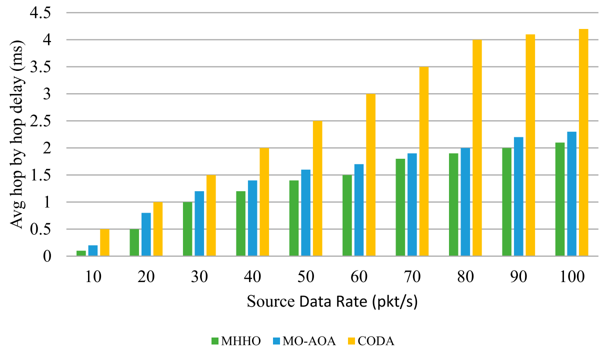

Figure 7. Average time among each hop of the suggested algorithm.

link layer communication and delay control packets. Figure 7's results make it abundantly evident that the suggested algorithm MHHO has shorter latency than MO-AOA and CODA, respectively, by 43% and 48%.

Figure 8(a) compares the suggested algorithm MHHO and the state-of-the-art method in terms of the packet delivery ratio over the number of rounds. It turns out that the packet delivery ratio is a throughput calculation metric; the better the packet delivery ratio, the better the network's throughput. The results show that the packet delivery ratio is greater for the suggested algorithm, ranging between 96% and 99%, as the quantity of rounds raised. Figure 8(b) compares the suggested method MHHO and the state-of-the-art algorithm in terms of node death % over the number of rounds. The results show that for all three methods, the death percentage of nodes grows as the quantity of rounds improved, and after 950 rounds or more, all the nodes are dead. Additionally, it is apparent that the suggested MHHO-based congestion control routing algorithm has a node death percentage ratio that is 30% and 50% lower than that of MO-AOA and CODA, respectively.

6. Conclusion

In order to increase delay performance by reducing congestion, the offered study introduced a novel congestion control approach (RACC technique) with MHHO. Based on buffer occupancy, RACC enhances the current congestion control procedure. The extended performance findings of the suggested approach outperform state-of-the-art algorithms in terms of different parametric metrics. As a result, the suggested algorithm transmits packets using the best data routing channel within the current round, reducing hop-by-hop delays, increasing packet delivery rates, or lowering node death rates, which eventually increase network throughput and lifespan, respectively. By applying the same scenario to wireless recharging models, the work may be expanded so that lifetime extension and congestion management can be solved simultaneously through the combination of RACC congestion control and suitable wireless recharging.

Disclosure statement

No potential conflict of interest was reported by the author(s).

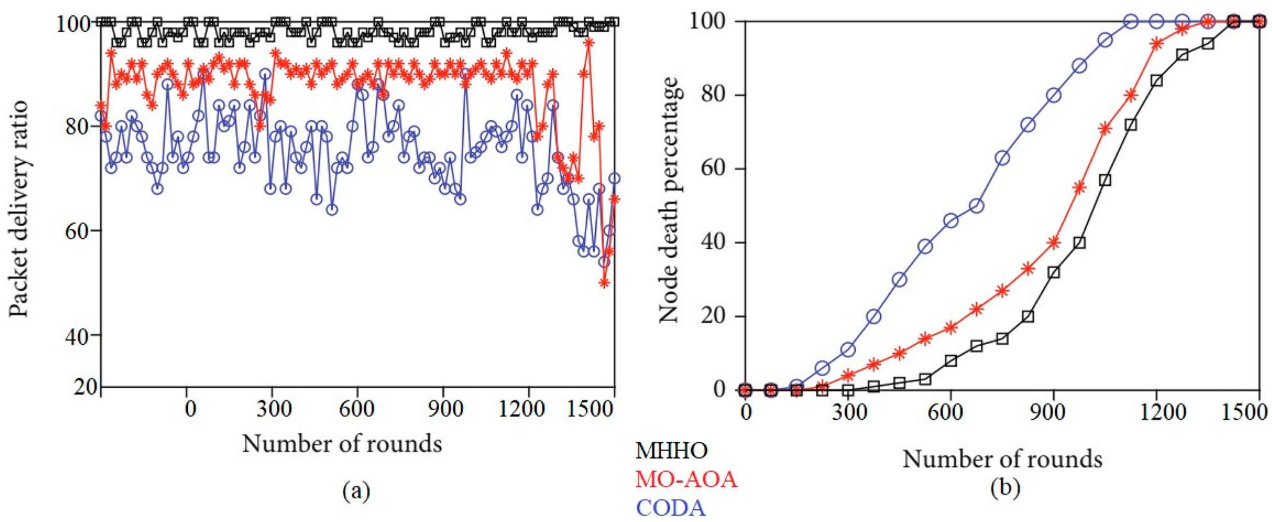

Figure 8. (a) Packet delivery ratio, (b) Node death percentage.

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