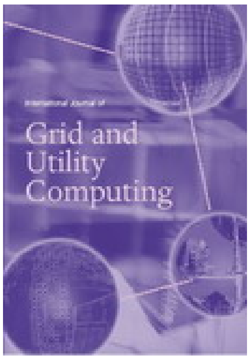

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Optimisation of the hybrid grey wolf method in cluster-based wireless sensor network using edge computing

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Abstract: Wireless Sensor Networks (WSNs) cover most of the secure data transfer applications and play a significant role in the IoT for primary data collection, which needs energy-efficient data transfer and improved network lifetime. The major challenge for these protocols is setting up optimum clusters and Cluster Head (CH) formation for efficient operation. WSNs have a critical role in parallel computation in which resources can be assigned to the sub-task and equalise the load, which improves the network lifetime. This paper uses the Grey Wolf Optimisation (GWO) algorithm in the proposed work by observing two variables, i.e., Residual Energy (RE) and node distance (DS) from Base Station (BS) that visualised and analysed the GWO under variable parameters in WSN. This approach identifies the most suitable node from all normal nodes for the selection of CH. The outcome demonstrates that using GWO improved the performance of the proposed model.

Keywords: base station; cluster head; energy efficiency; grey wolf optimisation; wireless sensor network.

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1 Introduction

WSNs are made up of many small sensor nodes, each responsible for sensing different events. Because all these nodes are powered by batteries, they have a limited lifetime. Each sensor node must have the ability to perform three critical tasks that include identifying important information, computing the observed data and communicating with other sensor nodes (Mao et al., 2014). The clustering method improves the throughput rate and hence, effectively enhances the network lifetime and system output reduces the energy dissipation, fault tolerance, durability and reduced latency (Singh et al., 2019). The clustering technique is similar to a network's partitioning into different groups, with one node acting as the CH for each cluster. All such CH in various clusters, coordinate communication and data aggregation between nodes. If the nodes coordinate for communication and data aggregation within their clusters, it is known as intra-cluster coordination. Furthermore, communication between observers from outside of clusters is known as 'inter-cluster communication'.

WSNs contain a significant number of distributed sensor nodes in the required area with limited battery energy that can collect data from the environment transmit it toward the BS as shown in Figure 1. The collected data from the BS are accessed by the authenticated user through the internet. Sensors are consisting of six main units, i.e., battery unit, sensing unit, microcontroller unit, ADC unit, memory unit and transceiver unit as shown in Figure 2. WSNs can be static or dynamic, solitary or multilevel and have static or dynamic nodes. Energy efficiency, region coverage and connectivity are critical factors for enhancing network throughput.

In recent years the application of WSN is increased in environment observation, defence surveillance, Industries and security. So, to minimise the cost of the network many researchers proposed a cluster-based WSN to increase its lifetime using a multihop and sleep and awake scheme. Although cluster-based WSN minimises energy consumption by taking responsibility to send the packets of its cluster node to BS or the nearest CH that applies a multihop technique to send the packets to BS. The nodes that collect similar packets of their neighbour can be in sleep mode and awake when required that also enhance the network lifetime.

1.1 *Motivation and contribution*

Network lifetime has an important role in WSN so many researchers proposed a protocol to minimise the battery utilisation of the network. The suggested protocol includes GWO approach for the selection of CH. Two parameters, RE and DS from BS, are also considered for CH selection which gives a better lifetime expectancy of the network. The following is a summary of our important contribution to the article:

- A new protocol is introduced for the better lifespan of the network and compared with TSEP and LEACH protocols.
- Although a literature review has been conducted and chosen a grey wolf optimisation method for a proposed protocol that selects clustering head in wireless sensor network and same has been implemented and compared with another model such as LEACH, etc.
- Complex tasks are decomposing into sub-task in WSN.
- Sensors having resources for sub-tasks are in awake mode.
- Sensors having other resources than sub-task remain in sleep mode.
- Multihop data transmission is done from CH to CH which improves the performance as compared to the TSEP and LEACH protocol, although RE and DS are considered in both proposed and compared protocols.
- The experiment is done for packets sent to BS and RE of the network.
- GWO approach finds the fittest nodes for the CH selection by using three dimensions α, β and Δ .

Figure 1 Building design of WSN (see online version for colours)

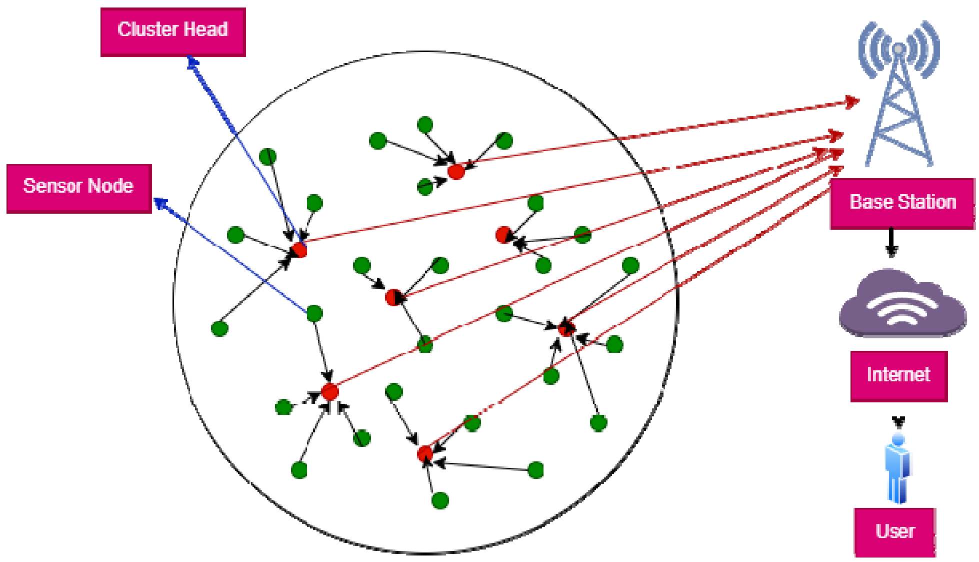
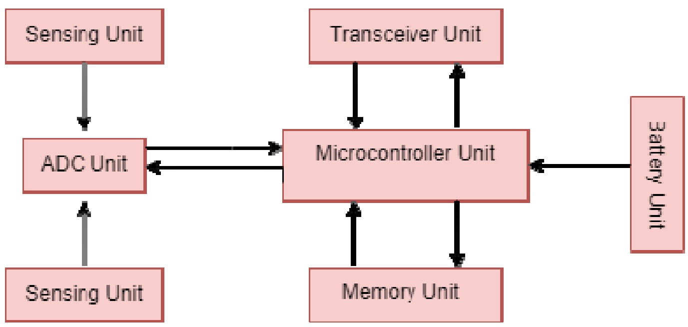


Figure 2 Components of sensor nodes



The remaining paper is described as follows: The related work is discussed in Section 2. The system description is covered in Section 3, the proposed protocol is covered in Section 4, the results are covered in Section 5 and the conclusion and future scope are covered in Section 6.

2 Related work

Recent development in WSNs has increased the interest of researchers towards it. This section covers the related works of researchers for energy efficiency and task allocation methods in WSN. Different routing protocols for WSNs are introduced to improve the lifespan of the network. For the researcher, designing an approach for a WSN that uses minimal resources is a crucial task for researchers. The WSN and IoT integration has a major task and hence is required to minimise the battery utilisation into the network. So optimal parameters are considered for the selection of CH for IoT-based networks.

Clustering involves the grouping of all the network's sensor nodes into clusters. A CH and member nodes are assigned to each cluster. CH collect data from its member and send it to a BS. Furthermore, as almost all the nodes only need to forward packets to the CH over a short distance and CH relay data to BS, the network's energy dissipation may be efficiently minimised (Hamida and Chelius, 2008). In Singh and Lobiyal (2012), Particle swarm optimisation has been employed based on natural selection mechanisms and genetic algorithms. Wang et al. (2004) proposed protocol builds network paths and genetic algorithms to optimise many things such as energy dissipation, packet delivery, coverage and connectivity, etc. In Idrees and Al-Yaseen (2021), Lifetime and coverage optimisation using a distributed genetic algorithm has been proposed that uses the technique based on three energy schemes: segmentation of the virtual network into sub-sectors, choice of dispersed CHs in each sector and scheduling of sensor activities that based on genetic algorithm optimisation. Guhan et al. (2021) introduced an energy-efficient dynamic CH selection based on the PSO method. The CH selection procedure that has been employed in this work is dependent on the computation of conventional data transmission distance and RE.

Chauhan et al. (2021) proposed a protocol for heterogeneous WSN using a DDMPE algorithm. Using benchmark functions, the proposed protocol has been tested and also compared with the existing techniques. The simulation's findings show that the suggested strategy is reliable and performs better than competing methods in terms of node RE, alive nodes over the rounds, dead nodes over the rounds, the lifetime of the network, throughput, etc. For selecting a CH based on energy awareness, Yadav and Mahapatra (2022) proposed a hybrid optimisation algorithm particularly known as particle distance updated sea lion optimisation for the hierarchical routing across WSNs. In addition to this, the author, using this approach to CH selection, has also taken care of the energy, distance, delay, as well as the network's level of service quality that has been compared to existing methods and proved to perform well. The author, uses the approach, in terms of the fitness function depend on the utilisation of RE, node density and ranking-based CH formation for non-CH nodes. Sarkar and Murugan (2022) proposed a protocol based on uniform, normal and gamma distributions to find the best CH by focusing on minimising delay, reducing the distance between nodes and maintaining energy stability. Kathiroli and Selvadurai (2021) introduced a technique for electing a CH that employs an energy distribution technique for the conservation of remaining power. The proposed method combines the sparrow search algorithm's search capacity at a high level with the dynamic potential of differential evolution to extend node lifetimes as well as to increase the throughput and energy efficiency.

The Grey Wolf optimiser possesses key advantages over other techniques, such as being simple to implement, having a simple structure, requiring little storage and computation, having the fastest convergent because of the sustainable reduction of search space and fewer decisions for controlling and tuning the operations in the protocol that results in the best stability and robustness (Hameed et al., 2016). Hence, it can be included in the proposed research problem to select optimal CH between SN for extending the lifespan of the network as well as retaining the energy for efficient data transmission. Singh et al. (2016) introduced a protocol in which CH selection is dependent on the RE of nodes to enhance the lifetime of WSNs. Kashaf et al. (2012) discussed a model for three-level heterogeneous WSN in which various levels have varying threshold energies, with the first-level nodes having the highest threshold energy and the third-level nodes having the lowest.

Rai and Daniel (2021b) proposed a protocol for better coverage and connectivity by using sleep and awake mode for overlapping sensor nodes. Narayan et al. (2020) introduced a protocol for two-level WSNs that considers two parameters, viz RE and smallest DS from BS and prolongs the network lifespan. Narayan and Daniel (2022a) discussed a protocol using sleep and awake technique for proper coverage and connectivity of the network that also improves WSN's lifespan. Rai and Daniel (2021a) introduced a protocol for three-level heterogeneous networks having different threshold energy considering two parameters, i.e., RE and DS from BS.

Jing et al. (2015) discussed a model based on quick sort scheduling. The tasks are put into the queue according to their priority. The priority of the task changes, so sorting is dynamic. This strategy executes every task whether they have low or high priority at a time. Yu et al. (2018) introduced a protocol that can do both static and dynamic task allocation through linear programming. This approach achieves consistent task distribution. Khan and Rinner, 2014) introduced a model that schedule the task according to their application within the network. This approach improves the coverage and connectivity of the network with better packet transmission. Zeng et al. (2015) proposed energy-efficient scheduling for all tasks with MILP. MILP minimise the calculation problems with linearisation.

Jiang et al. (2016) introduced an E2MR2 model that considers a bit of energy dissipation of the network. This technique finds the total battery utilisation of the network to improve its efficiency. Through this QoS of the network is also improved. Cirstea et al. (2013) discussed a reinforcement learning technique for task scheduling in WSN. This technique provides high-communication quality for mobile sensor nodes and minimises the traffic load in the WSN. Tomovic et al. (2016) discussed a new task-scheduling technique for energy-efficient WSN. The proposed model monitors the routing information and used the RE of the node as a variable for task allocation.

Yessad et al. (2012) proposed a model for multipath networking in WSN. In this protocol residual energy and communication energy are determined and improved with the forward node that reduces the overall load within the network. This approach enhances the network's lifespan by allocating the optimal task to the sensor nodes. Yin et al. (2017) introduced a protocol that gives prior distributed task allocation information to the sensor nodes. This approach improves the routing approach and minimises the energy consumption of WSNs. Yin et al. (2018) discussed a protocol based on the heuristic allocation of the task. The proposed model balances the load of the network, minimises energy consumption and hence improved its life expectancy.

Wen et al. (2022) discussed a task allocation protocol based on the available resource of the sensor network. The proposed technique decomposes the complex task into the subtask and hybrid GA and ACO algorithms are used to find the fittest node to assign the task

Senouci et al. (2019) discussed a model where packet transmission is based on three schemes: straight communication to BS, multihop communication and cluster-based communication. The cluster-based technique is applied to both static and dynamic networks. Cao and Zhang (2018) introduced a cluster-based WSN for static as well as dynamic nodes. For static networks, cluster formation is fixed and for dynamic networks, certain rules are applied for dynamic nodes. Das Adhikary and Mallick (2017) discussed a LEACH protocol based on cluster formation in the WSN. Although it was the first cluster-based protocol for the homogeneous network has some limitations with unbalanced clustering and RE not consider during the selection of CH.

Pachlor and Shrimankar (2017) introduced a modified LEACH protocol where SCH receives packets from CH and finally sends them to BS. Kumar and Pal (2013) discussed the A-LEACH protocol in which CH receives additional data from SN nearest to the BS in the cluster and sends it to the appropriate CH. Finally, this CH sends data to BS. Sivakumar and Radhika (2018) said that the LEACH protocol operates on the same principles similar to the LEACH-C procedure, but the steady phase in the network is different. Each node's position and RE are known to the BS. The protocol utilises this information to extend the network's lifespan. Yousaf et al. (2019) discussed the protocol where SN collects the packets and sent to the CH by using a multichip scheme. CH also communicate and sent packets to each other. The CHs aggregate the data and transmitted them to BS. The ideal route is taken for the delivery of packets to BS. The amount of hop counts for data transfer is reduced with multi-hop transmission, therefore, minimising the battery power consumption of the network.

Yazid et al. (2019) discussed a SEP two-level layered WSN protocol, i.e., normal level and advanced level. These two different levels have different threshold energies for the selection of CH. Islam et al. (2012) discussed the E-SEP protocol with three level heterogeneous network, i.e., normal, intermediate and advanced levels. These levels have different threshold energies for the CH selection process that improves the life expectancy of the network. Mittal (2020) discussed an MR-SEP protocol that is an enhanced version of the SEP protocol. The area is partitioned into different levels with different threshold energies and each level has its cluster and CH. The CH selection process depends upon the distance of a node from BS where packet transmission is done with a multihop technique from the inner layer to the outer layer. Han et al. (2016) discussed the relay node concept for the delivery of packets in the network to enhance the system output. Tang et al. (2020) proposed HEED where the selection of CH depends upon the node RE. The protocol reduces communication load and extends the lifespan. Meddah et al. (2017) introduced the EEDCA protocol in which the node location and RE of SN serve as the basis for the CH selection criterion. Rai and Daniel (2022a) introduced a model for the SCH selection process based on FIS that improves the network lifespan. Rai and Daniel (2022b) discussed a protocol in which intruder detection is introduced based on a known bit acknowledgement process. Tyagi et al. (2023) proposed a protocol based on the next cluster head selection process for heterogeneous WSN that reduced the energy consumption for the new cluster head selection process. Li et al. (2023) proposed a protocol that analysis the power consumption on different parameters of WSN and introduces energy-efficient scheduling to enhance the lifetime of the network. Alkanhel et al. (2023) proposed a hierarchal clustering protocol using Multi-Swarm Optimisation (MSO)-based genetic algorithms that select the efficient CH in the network. Shingare and Agnihotri (2023) introduced a protocol based on *k*-mean clustering using a genetic algorithm that selects efficient CH and balanced to prolong the network's lifespan. Narayan and Daniel (2022b) introduced an FBCHS protocol in which areas are divided into different zones with different energy levels of the network. The CH selection process is done on two parameters, i.e., maximum RE and minimum separation of a node from BS. The authors applied a FIS for the better life expectancy of the network. Zaidi and

Ahluwalia (2022) discussed a two-level hierarchal protocol in which the CH selection process depends on the RE of the node and its location in the network based on the VGDRA procedure.

3 System description

This section will describe the proposed protocol and methodology. The section starts with the formation of the region for the network, energy consumption the proposed research's experimental design. In the development of the region for WSNs, the CHs are chosen on a probability basis, and a criterion is determined for each CH in the classic clustering technique called LEACH protocol that considers two variables also, i.e., RE and DS from BS. The nodes then create a cluster by associating with every CH. The proposed protocol is further optimised using the grey wolf techniques. In addition to that, the network has been established such a way that the node-to-node communication distance and the CH and then CH to the BS have been turned down through a multihop routing technique.

The coordinates for the network and BS are shown in Table 1.

Table 1 Details about the WSN region's parameter

Region / *Coordinates*	*Field dimension in (metres)*	*Base station coordinates in (metres)*
X	100	50
Y	100	175

3.1 Deployment of sensor nodes

The base station and node distributed around the network's region are shown in Figures 3 and 4 below.

Figure 3 Sensor node distributed around WSN's region

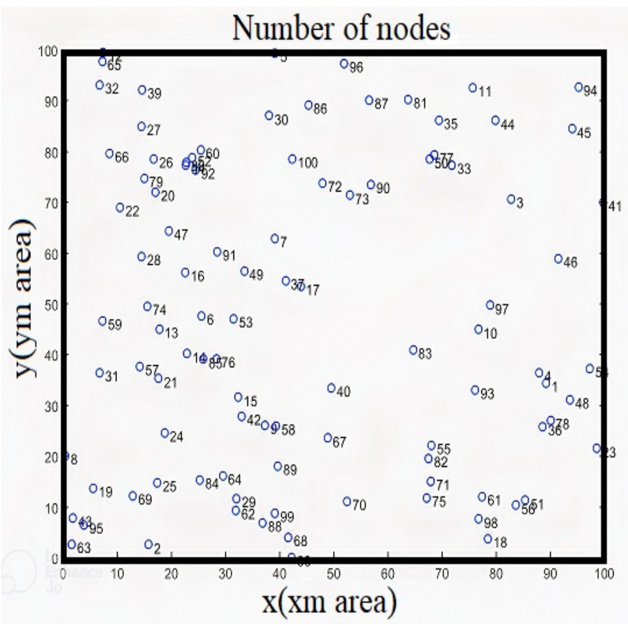
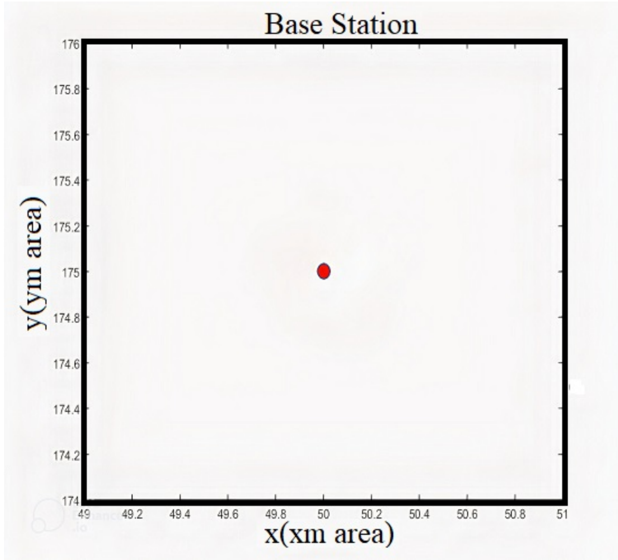


Figure 4 Base station at the centre of WSN's region



Deployment of nodes, CH selection and data transmission play a critical role in WSN. So following factors are considered during the deployment, data transmission and CH selection in the network.

- Sensor nodes with varying initial energy and with different resources are deployed in the required area.
- Since different types of nodes are deployed so the network is heterogeneous
- BS is in the mid of the network
- Multihop, sleep and the awake scheme are considered for proper data transmission and to reduce network energy consumption respectively.
- Cluster head selection depends upon two parameters, i.e., DS from BS and its RE.

3.2 Task allocation

The complex tasks in the proposed model are decomposed into individual sub-tasks. These individual sub-tasks are then assigned to the sensor nodes.

Individual sub-tasks contain three attributes viz resource needed *need_resource,* size of data task *data_task* and time needed for computation (self) *need_time.* Needed resource interpret by array $need\_resource = \left[a_1, a_2, a_3, ..., a_n\right]$ and a_i is *i*-th resource.

3.3 Energy consumption

The sum of the energy used for data transmission from Normal Nodes to CH constitutes the total energy consumption $\left(E_{TN}^{NN}\right)$ and from CH to BS $\left(E_{TC}^{CH}\right)$,

Data received by CH from Normal Node $\left(E_{R}^{NN}\right)$, Data process by NN $\left(E_{P}^{NN}\right)$

$$E_{NN} = E_{TN}^{NN} + E_{P}^{NN} \quad (1)$$

where

E_{NN} = Total energy consumed

E_{TN}^{NN} = Energy consumed during data transmission from normal nodes

E_{P}^{NN} = Energy consumed during data process by normal nodes

Energy consumed by normal nodes during data transmission is shown in equation (2)

$$E_{TN}^{NN} = \left(data\_task \times e_{cmp}^{NN} \times D^2\right) \quad (2)$$

where

$data\_task$ = Size of data

e_{cmp}^{NN} = Amplifier factor of Normal Nodes

D = Distance of CH from NN

Energy Consumed during data process is given in equation (3)

$$E_{P}^{NN} = P \times need\_time \quad (3)$$

where

P = Processed data power

$need\_time$ = Time needed to process a task

Total energy consumed by CH is shown in equation (4)

$$E^{CH} = E_{R}^{CH} + E_{TC}^{CH} \quad (4)$$

where

E^{CH} =Total energy consumed by cluster head

E_{R}^{CH} = Energy consumed during data received by CH

E_{TC}^{CH} = Energy used for sending data from CH to BS

Energy consumed during data received by CH is shown in equation (5)

$$E_{R}^{CH} = data\_task \times E_{P}^{CH} \quad (5)$$

where

$data\_task$ = Size of data

E_{R}^{CH} = Energy consumed during data process by CH

Energy used while data is being transferred from CH to BS is shown in equation (6)

$$E_{TC}^{CH} = \left(data\_task \times e_{cmp}^{CN} \times D^2\right) + \left(data\_task \times E_{p}^{CH}\right) \quad (6)$$

where

$data\_task$ = Size of data

e_{cmp}^{CH} =Amplifier factor of CH

D = Distance of CH from NN

E_{p}^{CH} = Energy consumed during data process by CH

3.4 Cluster establishment and CH selection

The process of CH formation of this protocol has been divided into two stages, the first one known as setup and the second steady. In beginning, the first phase has been initialised and then cluster formation is done in the second phase.

Algorithm: CH selection and cluster formation

CH: Cluster Head
$T(n)$: Threshold Energy
P: Likelihood of node being CH
Ni= *i*-th node
R: No. of rounds
n: Total number of nodes
m= Request message to join CH
k: Acknowledgement
E: RE of node
d: DS from BS
Start: Setup phase
  If (Alive node>0)
For round 0 to max
select a random number between 0 and 1
    If (Random Node's residual energy $\geq T(n)$)
      Selected as CH
    Else normal node
where

$$T(n') = \left\{ \frac{P}{1 - P(E,d)\left[r \bmod \left(\frac{1}{p}\right)\right]} \right\} \quad \text{If } n\varepsilon$$

End
  End
End
Start: Steady phase
  For node 0 to *n*
    Each CH sends message *m* to every node
    Ni node send message *k* to the nearest CH
    Ni become member node of CH
  End
End

Table 2 Abbreviation and definitions

S. No.	*Abbreviation*	*Definition*
1	CH	Cluster head
2	E_{eiec}	Energy dissipated for CH selection residual energy of network
3	R_{energy}	
4	ε_{fs}	Free space energy of amplifier
5	ε_{cmp}	Transmit energy of amplifier
6	D	Distance between nodes
7	T_{energy}	Transmission energy

3.5 Network model

For the proposed protocol, it has been assumed that a network is homogeneous with an area of 100 × 100 m^2 and has different numbers of nodes from 100 to 400 randomly deployed in the region. For the simulation of the proposed model, MATLAB has been used. The parameters taken for the simulation are shown in Table 3.

Table 3 Specifics of the model's parameters

Parameters	*Description*	*Value*
Eo	Initial energy of a Node	0.5 J
ETX	Energy used in data transmission	50×10^{-9} J/bit
ERX	Energy used in data receiving	50×10^{-9} J/bit
Efs	Energy used in data transmitting by the Amplifier when $d \le d0$	10×10^{-12} J/bit/m^2
Emp	Energy used in data transmitting by the Amplifier when $d > d0$	1.3×10^{-15} J/bit/m^2
P(*i*)	Node's probability to become a CH	0.05
Packet Length	Total length of data to transmit	6400 bit
	Operation	Energy dissipated
EDA	Energy used for data aggregation	5×10^{-9} J/bit
rmax	Maximum round employed while simulation	500 & 1000

3.6 Optimisation of cluster head formation using grey wolf algorithm

The GWO algorithm is a very unique meta-heuristic method that may be used for several optimisation problems. The GWO algorithm is inspired by the naturally occurring pyramid of leadership around the hunting mechanism of grey wolf packs. The decision variables can also be categorised based on the grey wolves' social dominant pyramid model. As a result, alpha (α) is the best and most optimised option, with beta (β) and delta (Δ) ranking second and third, respectively. Apart from these, all other solutions are considered omega (Ω) solutions, which are the least suitable. The optimisation process is governed by the α, β, δ and Ω and parameters and is based on the hunting process.

The GWO approach has been used to select the CH of the WSNs. The CH is typically chosen based on the sensor network metrics such as distance, energy and degree. Here, in the present work, it has been chosen based on the likelihood that the node will form a cluster that is optimised through the foundations of a fitness function using the GWO approach. The fundamental goal of the GWO is to choose the CHs inside the network to increase the network's longevity. Table 4 shows the value of various GWO variables that have been taken for the simulation of the network.

Table 4 GWO's parameters

Number of search agent	*Lower bound*	*Upper bound*	*Dimension*	*Number of iteration*
10	–5	+5	3	30

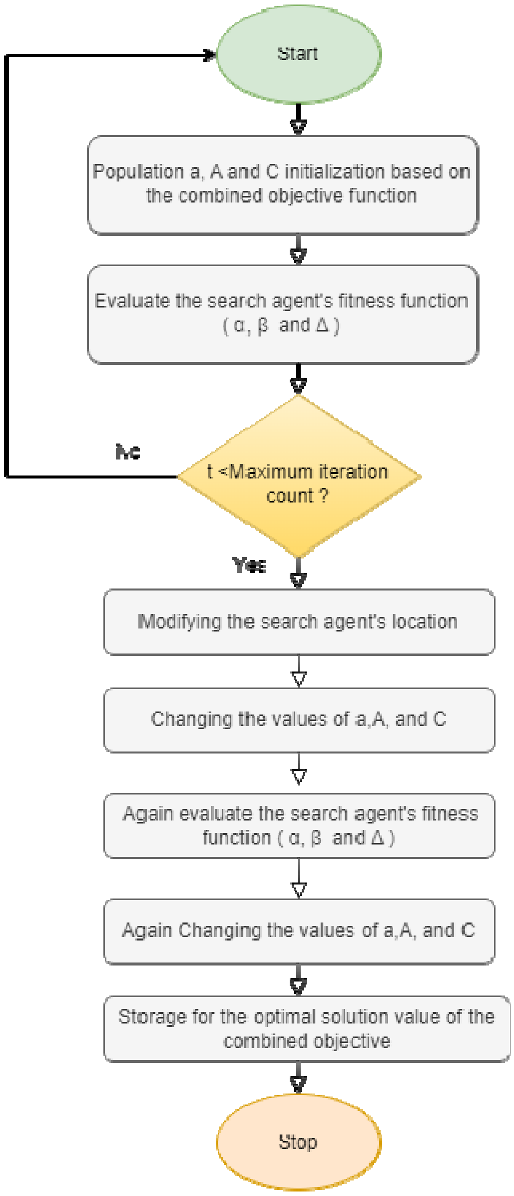
3.7 Proposed protocol

Pseudocode: HGWOH

```
Set up the M Grey Wolf Population (GWP)
Li(i = 1,2,...,m) in a random way.
Find out the fitness level of each participant.
Arrange the GWP by fitness levels
    α = Participant with most fitness level
    β = Participant with second most fitness level
    Δ = Participant with third most fitness level
      d1, d2, d3 are random numbers between 0 to 1
    0 = encircling coefficient
    D & E are coefficient vector
For max_Iter_range
    determine the value of p
      p= 2*(1 – Iter/ max_Iter_range )
    For i in range (M):  # for each participant
     a. Calculate the value of D1, D2, D3 and E1,
        E2, E3
        D1 = o*(2*d1-1), D2 = o*(2*d2-1), D3 =
             o*(2*d3-1)
        E1 = 2*d1, E2 = 2*d2, E3 = 2*d3
     b. Calculate L1, L2, L3
        L1 = α _.location
        D1*abs(E1* α _location – i-th_location)
        L2 = β _location
        D2*abs(E2* β _location – i-th_ location )
        L3 = Δ _ location
        D3*abs(E3* Δ _ location – i-th_ location )
     c. Calculate the fitness of the new solution
        L_new = (L1 + L2 + L3) / 3
        F_new= fitness( Lnew)
     d. Upgrade the i-th_participant greedily
        if ( fnew < i-th_ participant .fitness)
          i-th_ participant .location = Lnew
          i-th_ participant .fitness = fnew
    End-for
    # calculate new α , β and Δ
      sort GWP by fitness level
      α = participant with most fitness level
      β = participant with second most fitness close
      Δ = participant with 3rd most fitness level
  End for
Restore highest suitable participant in the GWP
\
```

Figure 5 shows the flow chart of GWO algorithm.

Figure 5 GWO algorithm with flow chart



4 Result and discussion

This section contains a comparative analysis that has been performed between Hybrid GWO Method (HGWOM), LEACH and TSEP protocol. Figure 6 illustrates the contrasting analysis in terms of the first dead node while

Figure 7 illustrates the contrasting analysis in terms of the last node dead. Table 5 illustrates the contrasting analysis for the proposed model.

Figure 6 First dead node (see online version for colours)

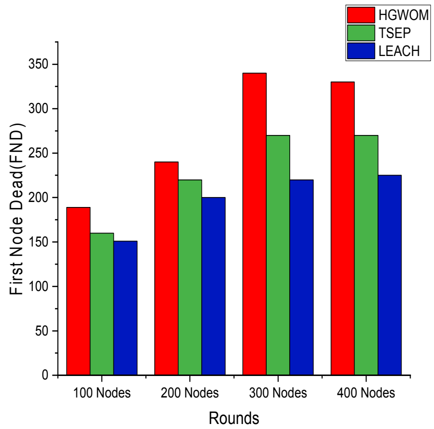


Figure 7 Last dead node (see online version for colours)

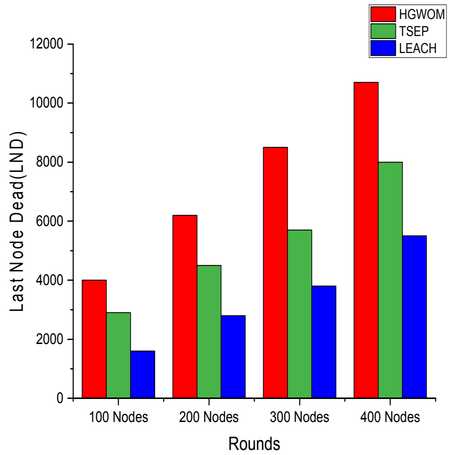


Table 5 First and Last node dead for 100, 200, 300 and 400 nodes

	First Node Dead				*Last Node Dead*			
	100 Nodes	*200 Nodes*	*300 Nodes*	*400 Nodes*	*100 Nodes*	*200 Nodes*	*300 Nodes*	*400 Nodes*
HGWOM	189	240	340	330	4000	6200	8500	10700
TSEP	160	220	270	270	2900	4500	5700	8000
LEACH	151	200	220	225	1600	2800	3800	5500

4.1 Proposed model evaluation based on packet to base station

This section evaluates the performance of the proposed model based on packet transmission to BS. For the comparative analysis of the proposed model (HGWOM) simulation has been performed at 500 rounds and 1000 rounds between HGWOM, LEACH and TSEP. Table 6 represents the comparative analysis of the proposed model.

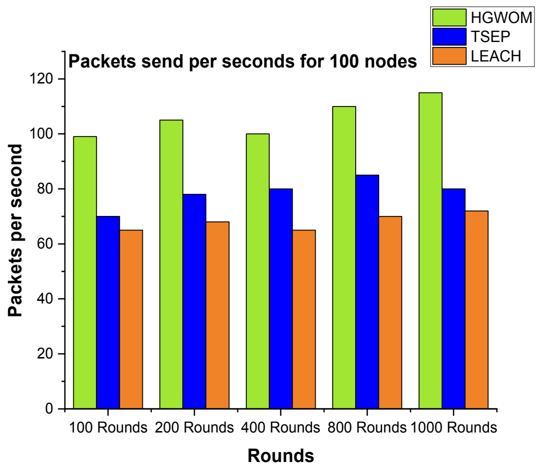
Table 6 Packets send per second for 100, 200, 300 and 400 nodes

	Protocols with number of nodes											
Rounds	*HGWOM-100*	*TSEP-100*	*LEACH-100*	*HGWOM-200*	*TSEP-200*	*LEACH-200*	*HGWOM-300*	*TSEP-300*	*LEACH-300*	*HGWOM-400*	*TSEP-400*	*LEACH-400*
100	99	70	65	200	180	150	310	250	200	390	340	300
200	105	78	68	180	168	150	300	242	210	400	335	310
400	100	80	65	182	165	145	290	245	180	380	330	305

Figures 8, 9, 10 and 11 depict the analysis in terms of packets send to BS for 100, 200, 400 and 300 nodes, respectively.

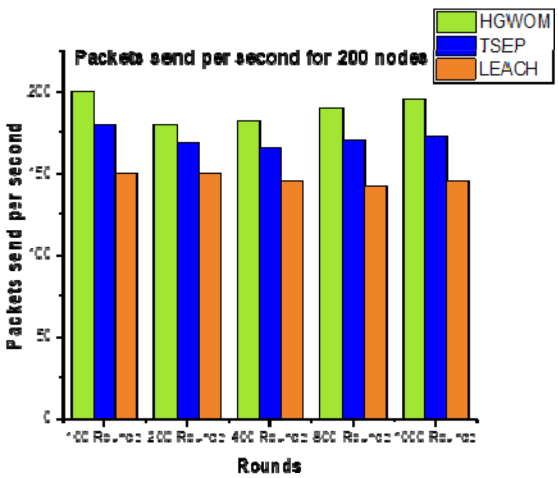
In Figure 8, HGWOM sends 99, 105 and 100 packets per second for 100, 200 and 400 rounds with 100 nodes where as TSEP send 70, 78 and 80 and LEACH sends 65, 68 and 65 packets per second for 100, 200 and 400 rounds with 100 nodes.

Figure 8 Packets sent to BS for 100 nodes (see online version for colours)



In Figure 9, HGWOM sends 200, 180 and 182 packets per second for 100, 200 and 400 rounds with 200 nodes where as TSEP send 180, 168 and 165 and LEACH sends 150, 150 and 145 packets per second for 100, 200 and 400 rounds with 200 nodes.

Figure 9 Packets sent to BS for 200 nodes (see online version for colours)



4.2 Proposed model evaluation based on residual energy

This section demonstrated the proposed model based on the RE of the network. Figure 10 depicted the RE at 1000 rounds for 100, 200, 300 and 400 node rounds between HGWOM, LEACH and TSEP. Table 7 represents the comparative analysis of the proposed model.

Figure 10 Packets sent to BS for 300 nodes (see online version for colours)

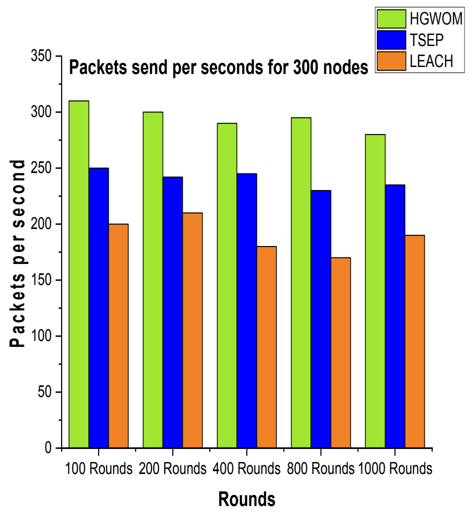


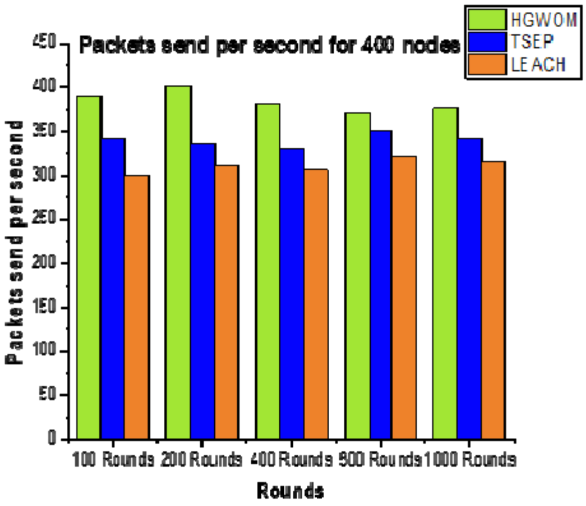
Table 7 Residual energy

Round (1000) \ *Nodes*	*Residual Energy*			
	100 Nodes	*200 Nodes*	*300 Nodes*	*400 Nodes*
HGWOM	42	80	135	170
TSEP	35	65	100	140
LEACH	20	45	70	100

In Figure 10, HGWOM sends 310, 300 and 290 packets per second for 100, 200 and 400 rounds with 300 nodes where as TSEP send 250, 242 and 245 and LEACH sends 200, 210 and 180 packets per second for 100, 200 and 400 rounds with 300 nodes.

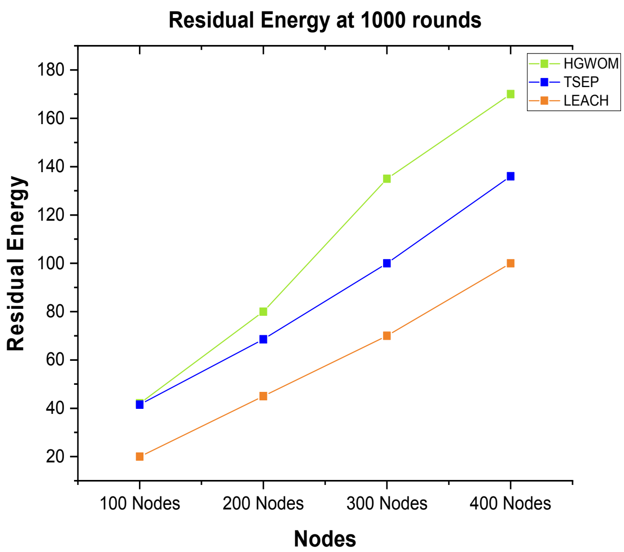
In Figure 11, HGWOM sends 390, 400 and 380 packets per second for 100, 200 and 400 rounds with 400 nodes where as TSEP send 340, 335 and 330 and LEACH sends 300, 310 and 305 packets per second for 100, 200 and 400 rounds with 400 nodes.

Figure 11 Packets sent to BS for 400 nodes (see online version for colours)



In Figure 12, the RE of HGWOM protocol 42, 80, 135 and 170 for 100, 200, 300 and 400 nodes respectively whereas in TSEP 35, 65, 100 and 140 and LEACH 20, 45, 70 and 100 for 100, 200, 300 and 400 nodes, respectively.

Figure 12 Residual energy (see online version for colours)



5 Conclusion and future scope

In the proposed research work, a model called HGWOM has been proposed for CH selection depending upon probability and has been optimised using the Grey Wolf Optimisation. The fittest node is determined using a hybrid approach of GWO and LEACH protocols by taking into account the node's RE and DS from the BS. The identified fittest node can take part in the CH selection process. For simulation, the region of interest has been taken as 100 × 100 m^2 wide, containing the variable number of nodes of 100, 200, 300 and 400, respectively. The outcome was examined for each number of nodes for which the proposed model was examined. A comparative analysis was also performed between the proposed model, LEACH and TSEP protocols, which depicted that the proposed model conducted magnificently in terms of various performance parameters such as dead node/alive node per round in which HGWOM first node dead at 189, 240, 340 and 330 rounds for 100, 200, 300 and 400 nodes respectively as compared to TSEP and LEACH protocol and last node dead at 4000,6200,8500 and 10700 rounds for 100, 200, 300 and 400 nodes, respectively, packet per second to BS for HGWOM are 99, 200, 310 and 390 for 100, 200, 300 and 400 nodes, respectively and residual energy of HGWOM are 42, 80, 135 and 170 joules for 100, 200, 300 and 400 nodes, respectively. The experiments were done only for the static and homogeneous network so in the future, the experiment will be expanded to include heterogeneous and dynamic networks as well as energy-efficient networks for intrusion detection and proper coverage and connectivity in the target area of WSN.

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