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Improving Energy Efficiency By Optimizing Ch Selection Strategy And Optimal Relay Node Selection Process In Wsns

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Abstract
In WSNs, a major challenge is achieving energy efficiency. The limitation in energy and its consumption is a significant problem and needs to be addressed with effective and reliable solutions. To decrease the energy conservation for wireless sensor networks (WSNs), clustering is used as an efficient method. Most of the clustering algorithms cluster the network and selects CH for easy management of the clusters. But, these clustering algorithms have specific restrictions like higher execution time especially for large scale network that increases the overhead of a network. Optimal relay node selection is a crucial task to save more energy as improper node selection leads to unnecessary energy utilization in sensor nodes. So there is a need of developing a combined algorithm that optimizes both clustering and optimal relay node selection processes. Here we introduce a new energy efficiency management algorithm, MGSA-ORS (Modified Gravitational Search algorithm for optimal relay node selection). This algorithm selects CHs based on multiple parameters like the sensor node's closeness to the BS, residual energy, and probability value. Owing to the distance between nodes, sensor node distance to BS is considered to avoid the unnecessary utilization of energy. Also, the proposed MGSA considers every node's distance from their respective CHs and residual energy and delay in the links as the major parameters for relay node selection. By comparing with the other existed techniques like LEACH (low energy adaptive clustering hierarchy), the proposed algorithm out performs the other protocols in terms of energy efficiency, improved data delivery rate, and network lifetime. Approximately 25%-30% energy is saved with the help of an efficient CH selection strategy and MGSA optimal relay node selection method.

Keywords: *Cluster head, Energy efficiency, Gravitational Search Algorithm, LEACH, Network lifetime, Relay node, WSN.*

1. INTRODUCTION

In wireless communication, an important role is played by WSNs or wireless sensor networks. It includes different kinds of applications in healthcare, civil, and military fields. To sense the information of temperature level, humidity, and pressure constraints, nodes are included in the wireless sensor networks. The information on the physical area can be collected by the nodes and they will make the transmission that data to the base station (BS) [1].

WSNs are significant devices in the IoT paradigms. The parameters of WSNs like energy efficiency, resilience, and autonomous are rendered a vital candidate to dominate the IoT framework's information collection [2]. The sensor nodes will exchange data with the cluster head (CH) in the network and it will act as a data aggregator. However, the aggregated data is transferred to the BS by CH. Due to the essential fusion role, the sensor node's information is aggregated in CH and it helps to reduce the sending of data to the BS. Hence, the bandwidth resources and energy are saved. In organizing applications, the cluster is utilized widely in which naturally inspired techniques are implemented for integrating spatially closed sensor nodes to gain the benefit of reduced redundancy and correlations in the readings of a sensor [3].

To manage the network topology and medium access control, the technique of multi-hop routing is applied that will result in weighty overhead. The more effective one is a direct one-hop routing when all sensor nodes near to the BS node [4]. In other cluster-based track protocol, the portion of a CH has been focused on a particular area that is not suitable for crucial applications requiring more time. The energy utilization reduces by the cluster-based track protocol which uses a space for each CH for forwarding of aggregated information to BS [5].

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As per the literature review, the main objective is the minimization of reduced energy conservation. The clustering scheme employment is one of the methods to decrease such energy utilization. The definition of clustering is described as the process of determining a natural association among some particular objects or data or the grouping of similar objects. The clustering technique is effectively utilized in WSN to optimize the energy consumption, particularly in dense networks. However, reduction of total energy consumption occurs in a system. The most common method is concerned as multi-hop routing and clustering to enhance the network's energy efficiency. Instead of allowing each node in a network, the nodes are formed as groups known as clusters to forward the data to the BS directly. From other cluster member nodes, the CH node will gather the information and forward that processed data to BS. Such type of scheme has an advantage of twofold. To decrease the unwanted redundancy, the collected information from cluster member nodes can be compressed by the CH node in the first phase. Secondly, most of the nodes are allowed to transmit the information to nearer CH nodes, and the multiple hop communication to CH nodes only is limited that improves the energy efficiency greatly.

NOVEL SCHEME

Energy efficiency is the major challenging task in WSNs. Clustering is a proven solution for WSNs to achieve energy efficiency. But, most of the existing clustering algorithms failed drastically in CH selection which leads to an increase in energy consumption. The optimal selection of the relay nodes efficiently decreases the energy utilization of the sensor nodes. Therefore, we introduced a new energy efficient algorithm, MGSA-ORS with novel CH selection parameters, and a modified gravitational search algorithm for optimal relay node selection. This algorithm selects CHs using multiple parameters like BS distance, residual energy, and probability value. The sensor node distance to BS consideration avoids unnecessary energy utilization due to the distance between the nodes. Also, the proposed MGSA considers every node's distance from their respective CHs and residual energy and delay in the links as the major parameters for relay node selection.

- The proposed method improves the efficiency of CH over the previously proposed clustering protocols.
- The network lifetime is improved due to the optimal relay node selection and introducing modified GSA.
- The data sharing between CH and BS is optimized as the CHs are selected according to BS distance to achieve energy saving.
- End-to-end delay of the data transmission is minimized due to the inclusion of nodes delay is the significant metric for optimal relay selection in MGSA.

The research paper's remaining sections describe as follows. The presentation of some of the recent researches regarding energy-efficient clustering protocols in WSNs is made in section 2. The proposed approach is demonstrated in section 3. The simulation parameters are represented and discussion of simulation results has mentioned in section 4 and section 5 concludes the paper.

2. LITERATURE SURVEY

Rout et al. [6] was proposed tree-based rechargeable sensor networks to determine energy usage. In [7], the network coding and duty cycle are considered to compute the network lifetime with upper bounds.

Neamatollahi et al. [8] has discussed a proposed mechanism of fuzzy-based hyper round policy for determining a solution for the problem of re-clustering overhead in a WSN. Based on the fuzzy logic and particle swarm optimization [9], network lifetime improves using the cluster head selection. By using unequal cluster formation and proper selection of cluster head, a fuzzy-based unequal clustering algorithm was improved to determine the hotspot issues in a WSN [10]. For a heterogeneous sensor actor-network, the variable states consider in the delay and energy-aware routing protocol using a fuzzy logic.

Pantazis et al., [11] presents a study on the wireless sensor networks with the implementation of energy-efficient routing protocols. A path cost determines including the link layer's number of transmissions with the inclusion of link quality and relative ordering of links in a wireless mesh network [12]. Rout et al., [13] proposes an algorithm of network coding-based probabilistic routing for cluster-based WSNs.

Zhang et al. [14] has been discussed an energy balancing routing protocol which helps to choose the next node based on the forward energy density and the link weight. For a duty-cycled WSN, an opportunistic

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routing protocol [15] was proposed that includes the consideration of residual energy with an algorithm of forwarder selection.

Sun et al., [16] proposes an ant colony optimization-based routing algorithm by considering the residual energy, transmission direction, and transmission distance for the communication of nodes. For achieving efficient routing decisions, a routing parameter, link quality, distance, available free buffer, and residual energy are considered.

Sindhwani and Vaid (2013) discuss the vice cluster head with low-energy adaptive clustering hierarchy that improves the complexity level for the LEACH(low energy adaptive clustering hierarchy) protocol.When a cluster head damages, it operates on a vice cluster head that helps to minimize the huge amount of choosing a new cluster head every time. Thus, the network lifetime enhances [17].

Liao and Zhu (2013) considers the energy-balanced clustering algorithm that relies on the LEACH protocol by considering the distance agents and remaining energy. The selection strategies of optimal cluster head could improve not choosing the cluster head [18].

Bakaraniya and Mehta (2013) have proposed K-LEACH protocol for improving a sensor network lifetime based on the k-medoids and normal clustering algorithms. The overall network capacity is scaling among all active nodes. The network lifetime enhancement assures with the normal clustering of nodes based on the proper placement of CH. Once the random round operations completed with 50%, the protocol chooses the CHs, clustering union, and the maximum remaining energy criterion. The LEACH protocol provides a total random selection of CHs that results in an improved lifetime, reduced energy consumption, and not processing a proper selection of CHs in a network [19].

Kole et al. (2014) has proposed a technique of distance-based cluster formation for achieving the increased lifetime based on the LEACH protocol. The determination of a node distance from BS is very important in the formation of a cluster that helps in reducing other transference in the current LEACH protocol [20].

Sai Krishna Mothku et al. and Rashmi Ranjan Rout et al. [21] were proposed a mechanism of fuzzy-based delay and energy-aware intelligent routing to select efficient routes. By using the network resources like distance or proximity, available buffer size, quality of link, and residual energy, the routing decisions have been made using a fuzzy logic system in the proposed mechanism. There is a chance of getting a node with good link quality, higher availability of free buffer, and close distance, and more residual energy has been turned as a next hop node in a routing path.

Amer O Abu Salem et al. and Noor Shudifat et al. [22] were focused on enhancement of LEACH protocol to overcome the aforementioned limitations and proposed a clustering routing protocol which is extended for LEACH protocol through the detection of a cluster head based on the distance with lowest degree from the BS. This protocol has been used for reducing the cluster head nodes' energy consumptionacross the overall network. The proposed LEACH protocol has a capability of achieving the improved lifetime of a network and minimization of conservation of energy.

The existing methods of FEARM[21] and ELEACH[22] protocols have included the drawbacks of increased routing overhead and higher rate of inactive nodes and increased consumption of energy respectively. To overcome these issues, the technique of MGSA-ORS is proposed for increasing the performance of a network with the cluster head selection effectively.

NETWORK MODEL

By considering the following properties, a wireless sensor network is designed. Here, the sensors are stationary after deployment the nodes randomly over the network area. All of the nodes featuring homogeneous and having equal capabilities in the configuration of nodes for communication and processing. However, the number of sensors n, number of CHs m, and one BS. Additionally, some assumptions have considered such as each sensor node belongs to CH only, and periodical sensing performs, and data send to their respective CH. Based on the control packets, the broadcasting of information by sensor nodes is done and share residual energy, and information about location with the neighboring nodes.

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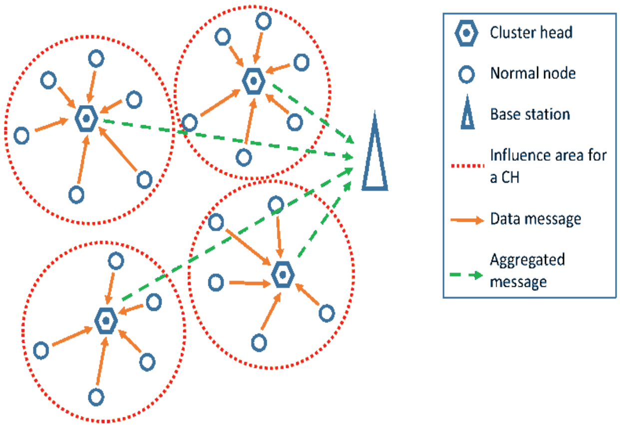

Figure 1. Gravitational Search Algorithm

One of the natural techniques is the gravitational search algorithm (GSA) which can use for determining the solutions for NP-hard problems approximately. In 2009, E. Rashedi had devised the problems using the law of gravity. Figure1 shows that Gravitational search algorithm.

According to the Newtonian law of gravity and motion, GSA is defined as "Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them". Agents consider as objects in GSA and their masses evaluate the performance. Through the gravity force, all these agents or objects could attract each other. Four different specifications include for every agent such as inertial mass, passive gravitational mass, active gravitational mass, and position.

POSITION

The considered problem's potential solution represents using each agent in GSA. An agent's each dimension initializes randomly in the process. i_{th} agent can be described as follows:

$$A_i = (A_i^1, A_i^2, A_i^3, \dots \dots A_i^d \dots \dots A_i^n) \quad \text{for i=1,2,...N}$$

Where, A_i^d represents the i_{th} agent d_{th} dimension.

ACTIVE GRAVITATION MASS

The gravitational field strength applied by a particular object is measured for active gravitation mass. By comparing with the larger object, the small active object has weaker gravitational field. The fitness value is equivalent to the gravitational mass.

PASSIVE GRAVITATION MASS

The strength of object that interacts with the gravitational field is measured for passive gravitation mass. A smaller force experiences for an object that has a smaller passive gravitational mass than a larger one in the gravitational field. The fitness value is directly proportional to the passive gravitation mass.

MAPPING SCHEME

For computing the mass from fitness value, mapping scheme uses which express using below Eq. (1)

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \quad (1)$$

Where, best (t) refers to the maximum fitness value at time t, worst (t) indicates the value of minimum fitness, and $fit_i(t)$ refers to the ith agent fitness. With the addition of small value ϵ, mass $m_i(t)$ adjust accordingly as it can't be zero as shown in Eq. (2)

$$m_i(t) = \frac{fit_i(t) - worst(t) + \epsilon}{best(t) - worst(t)} \quad (2)$$

FORCE

The force formulates as follows that act on mass i from mass j in d^{th} dimension at time t is shown in Eq. (3)

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$$f_{i,j}(t) = \frac{G(t) * M_{p,i}(t) * M_{a,j}(t)}{R_{i,j}(t)} (A_j^d(t) - A_i^d(t)) \quad (3)$$

Where, $M_{a,j}$ and $M_{p,i}$ indicate the active and passive gravitational mass respectively, and $R_{i,j}(t)$ refers to the Euclidean distance between two agents i and j.

ACCELERATION

Acceleration is demonstrated by using Eq. (4) where, M_{ii}describes as the ith agent inertial mass that computes the object's resistance when it is implementing the gravitational force

$$a_i^d(t) = \frac{f_i^d(t)}{M_{ii}} \quad (4)$$

VELOCITY AND POSITION UPDATE

An agent's each dimension updates after generating the acceleration value based on the position and velocity based on the following Eq.(5 & 6) respectively.

$$V_i^d(t+1) = r * V_i^d(t) + a_i^d(t) \quad (5)$$

$$A_i^d(t+1) = A_i^d(t) + V_i^d(t+1) \quad (6)$$

Where, V_i is velocity, r is a random number in the interval [0, 1], and a_i^d is an acceleration and A_i^d is position of i_{th} agent in d_{th} dimension at time t.

KBEST CALCULATION

Based on the controlling of exploitation and exploration, the GSA's performance can increase. Kbest function utilizes as described in the Eq. (7) for achieving the aforementioned purpose:

$$K_{best} = round(N_p * {}^{K_{best}}/_{100}) \quad (7)$$

Where, N_p is the number of agents.

3. PROPOSED FRAMEWORK

For energy-efficient protocols, one of the popular methods is the clustering in WSNs. In the performance of these techniques, an essential role is played by the selection of CHs and data aggregation. Sensor nodes' energy consumption can affect by these factors over the network. A new objective functions propose for estimating the selection of CHs and optimal relay node for communication of data. Then we used a Modified Gravitational Search Algorithm to solve these objective functions. In this work, we used the modifed version of GSA to fnd the best solution. The computations and operations of the proposed method implement in the sensor nodes, where all the nodes have an equal amount of energy initially.

The operation of MGSA-ORS categorizes into rounds in which two phases include each round:

- Set-up phase
- Steady state phase.

In the set-up phase, the multi-path selects from each cluster member to the CHs and the BS and the clusters' organization have accomplished. In the steady-state phase, the information transmits. In the reduction of network overhead, high performance results in the steady-state phase than the set-up phase. The proposed system's block diagram represents in Figure 2 for efficient optimization of relay node and cluster head.

In the sensor nodes, the setup phase computations implement in the proposed technique. The data share by all sensor nodes that include distance to the BS, and remaining energy. The set of cluster head candidates with the close proximity to BS and high energy level determine by the sensor nodes in the cluster.

3.1. SET-UP PHASE

In the following phases, the set-up phase is included:

- Cluster-head selection
- Cluster formation

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The selection of cluster heads is performed in the set-up phase. From each cluster head to the BS, the clusters form and multi-hop path selects.

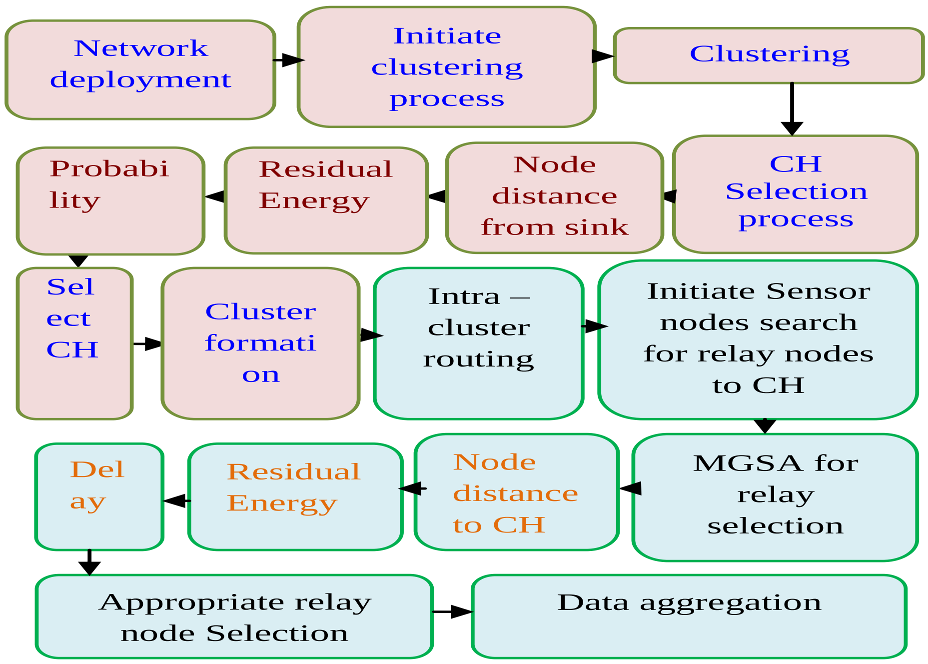

Figure 2. Block diagram of proposed system.

3.2. GSA BASED CLUSTER HEAD SELECTION:

Based on a probability value, distance between the BS and sensor node, and energy, a set of possible CHs choose by using the algorithm.

DERIVATION OF FITNESS FUNCTION FOR CH SELECTION

By considering the distance to the BS, and remaining energy, the fitness function formulates as follows:

(a) Energy: The data transmit to the respective CH by all member nodes and the received data aggregate by CH, and conversion of single transmission packet is done. Then, the forwarding of packets toward the BS. In this way, CH consumes more energy compared to the remaining sensor nodes. Therefore, a sensor node with higher residual energy is a more prominent choice as a CH, it means that energy consumption is less for low energy nodes and more for high energy nodes. So, our first objective is f_1 which can be minimized by using Eq.(8).

Objective 1

$$f_1 = \sum_{i=1}^{m} \frac{1}{E_{CHi}} \tag{8}$$

(b) Distance: It computes the average distance between the BS and the sensor node. It will reduce the CH nodes' energy consumption when it has minimum. Thus, the lifetime of CH prolongs. The second objective f_2 can minimize as Eq.(9)

Objective 2

$$f_2 = \sum_{j=1}^{m} (\sum_{i=1}^{Ij} dis(S_i\,, BS)) \tag{9}$$

(c) Probability value: It is the random number generated by the sensor nodes during CH selection. In some rare cases, two or multiple sensor nodes might have similar f_1&f_2 values. In those cases, the probability value determines the CHs. Hence, the second objective f_3 can minimize using below Eq. (10)

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Objective 3

$$f_3 = \sum_{i=1}^{m} \Pr(S_i) \tag{10}$$

All aforementioned objectives not conflict to each other. By using multiple objectives, weighted sum approach applies for frame single objective function given with Eq.(11). Where, α1, α2 & α3 are the weighted value assigned to each objective.

$$fitness = \alpha 1 \text{ x } f_1 + \alpha 2 \text{ x } f_2 + \alpha 3 \text{ x } f_3 \tag{11}$$

Where, $\sum_{i=1}^{3} \alpha_i = 1; and\ \alpha \in (0,1)$

3.3. ALGORITHM FOR CH SELECTION

Input:

Set of sensor nodes S = $(s_1, s_2, s_3 \ldots., s_n)$

Number of agents: N_p; Dimension m; Kbest = N_p

Result: set of CHs

##

Initialize the agents $A_i, where\ 1 \leq i \leq N_p$

While (i!= N_p) do

Calculate fitness(A_i) Eq (11)

End

While (i!= N_p) do

best = maximum (fitness(A_i))

worst = minimum (fitness(A_i))

End

While (i!= N_p) do

Calculate mass(A_i) using Eq 2

End

While (i!= N_p) do

While (j!= $Kbest$) do

Calculate force (A_i) using Eq. 3

Calculate acceleration (A_i) using Eq. 4

Update the coordinateCH_iusing Eq 5&6

Update the Kbest using Eq. 7

End

End

Assign sensor to CHs

End

3.4. CLUSTER FORMATION

CH_ADV (cluster head advertisement) message has been sent by BS to its neighbours after completion of the successful selection of cluster heads. Here, the neighbour nodes are propagated based on the cluster heads outwards. The nearest cluster head is chosen by each member node from the received messages of CH_ADV according to their signal strength. The node is sending information to the BS directly if in a case that the

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lower direct communication cost to BS exists when there is no cluster head to join for a sensor node. Otherwise, the cluster with the nearest cluster head is decided to join by it. The JOIN message is sent to the cluster head by a node once every node has been decided on the cluster in which it is belonged to. A communication schedule is created if a cluster head is received the JOIN message from all nodes which would have been showed an interest to join in the cluster and the schedule is broadcasted to all member nodes. Thus, the organization of clusters is possible.

3.5. STEADY STATE PHASE

In the steady-state phase, the data transmission is occurred. By using multi-hop paths, both inter and intra-cluster communication involve in the network. Using the parameters like residual energy, delay, and the distance between CH and member nodes, the selection of optimal relay node is performed.

DERIVATION OF FITNESS FUNCTION FOR OPTIMAL RELAY SELECTION

(a) Distance between member and CH: It is the average distance between the sensor node and their respective CHs. Maximum distance means maximum hops are involved which could increase the energy consumption of the sensor nodes. The first objective r_1 can minimize as Eq.(12)

Objective 1

$$f_1 = \sum_{j=1}^{m}(\sum_{i=1}^{Ij} dis(S_i , CH)) \tag{12}$$

(b) Residual Energy: All member nodes transmit data to their respective CHs through relay nodes. The minimum energy node may die or stop functioning during data transmission due to insufficient energy. The minimization of second objective r2 can be evaluated as Eq.(13)

Objective 2

$$f_2 = \sum_{i=1}^{m} \frac{1}{E_{Si}} \tag{13}$$

(c) Delay: It is the transmission time delay exists between the sensor nodes. If the delay increases, then energy consumption also increases in the network. The relay nodes should have minimum time delay for efficient data transmission.

The delay of the node directly depends on the expected transmission count (ETC) of the node, propagation delay of the node, and the transmission delay of the network.$r_3$can minimize as Eq.(14)

Objective 3

$$f_3 = \sum_{i=1}^{m} \min(D_{Si}) \tag{14}$$

The delay can be formulated as Eq. (15)

$$Delay\ D(t) = \sum_{i=1}^{m} ETC_i(t)(TD + PD_i) \tag{15}$$

Where, the term $ETC_i(t)$ indicates the expected transmission count of the i_{th} node at the time t. The term PD_i refers to the i_{th} node's propagation delay, and the term TD indicates the network's transmission delay. The node's ETC relies on the received packet delivery ratio of the node and the forward packet delivery ratio at time t. It can formulate as Eq. (16)

$$ETC_i = \frac{1}{F_i(t) * R_i(t)} \tag{16}$$

Where, the term $R_i(t)$ represents the received packet delivery ratio of the i_{th} node, and $F_i(t)$ refers to the forward delivery packet ratio of the ith node at time t. So the final fitness function can be derived as Eq. (17)

$$fitness = \alpha 1 \text{ x } r_1 + \alpha 2 \text{ x } r_2 + \alpha 3 \text{ x } r_3 \tag{17}$$

Where α1, α2 & α3 are the assigned weighed values for each objective and $\sum_{i=1}^{3} \alpha_i = 1; and\ \alpha \in (0,1)$

3.6. Algorithm for Optimal relay selection

Input:

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Set of sensor nodes S = $(s_1, s_2, s_3 \ldots., s_n)$

Number of agents: N_p; Dimension m; Kbest = N_p

Result: Set of Optimal relay nodes

##

Initialize the agents $A_i, where\ 1 \leq i \leq\ N_p$

While (i!= N_p) do

  Calculate fitness(A_i)   using Eq 17

End

While (i!= N_p) do

  best = maximum (fitness(A_i))

  worst = minimum (fitness(A_i))

End

While (i!= N_p) do

  Calculate mass(A_i)   using Eq. 2

End

While (i!= N_p) do

  While (j!= $Kbest$) do

    Calculate force (A_i) using Eq. 3

    Calculate acceleration (A_i) using Eq. 4

    Update the coordinate using Eq. 5&6

    Update the Kbest using Eq. 7

End

End

Select the relay nodes for each route using maximum (fitness(A_i))

End

4. RESULTS AND INTERPRETATIONS

4.1. EXPERIMENTAL SETUP

To assess the proposed method’s performance, the simulation is conducted by comparing it with two different schemes. NS2 network simulator utilizes in the project because it is a discrete event-driven and object-oriented network simulator that targets the research of networking. The support of routing, UDP, and multicast protocol simulation is provided on all wireless networks.

In this work, the network model is used in which fixed sensor nodes in a network are existed with homogeneous types with the same radio-transmitter devices, same capabilities, and constrained power resources, having the same initial energy, and uniform deployment. Here, the location of BS is static and distant away from the sensor node. By using static nodes and plane coordinates, the simulation tests are conducted. Limited energy nodes are assumed and the transmission or reception of information can be restricted after the node's initial energy is used up. The simulation parameters are included while performing the test and they are mentioned in this below table 1.

Table1: Simulation table

PARAMETER	VALUE

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Application traffic	CBR
Antenna type	Omni antenna
Transmission rate	1024 bytes/ 1ms
Radio range	250m
Packet length	1024 bytes
Routing Protocol	AODV
Simulation time	100s
Number of nodes	50
Area	1000 x1000m
Routing methods	MGSA-ORS, FEARM [21], ELEACH [22]
Transmission Protocol	UDP
Initial Energy	100J

IMPLEMENTATION PROCEDURE

AODV is taken as the protocol for proposal algorithm implementation because it is well coded and convenient to modify. AODV protocol consists of several functions from route discovery to route maintenance. *AODV::sendRequest, AODV::sendReply, AODV::recvRequest, AODV::recvReply* are some of the functions to allocate and broadcast the *RouteRequest(RREQ) & RouteReply(RREP)* control packets to establish a routing path. Also, It contains several timers (Ex: *HelloTimer*) to control the functions.

In our work, we have created separate functions, named *CH_selection & Cluster_formation* , for both selection of cluster head and formation of cluster respectively. In CH_selection function, nodes distance to BS, energy are calculated using Euclidean distance function & *Energymodel()* functions respectively. *energy-model.h* file is invoked to determine the residual energy of the nodes. The calculated fitness values are stored in an array called *"ch[k]"* (k : array size) and the eligible CH nodes are identified by comparing the array values.

In the *cluster_formation* function, the sensor nodes are divided as clusters based on their location on the network field and assigned to their respective CHs. In our simulation, the node's (x,y) coordinates are considered as the node location. After choosing the cluster head and formation of a cluster, the optimal relay nodes are selected during data transmission. For that, *aodv_packet.h* file (contains the header format of reply packet) is modified with an additional fitness field *(double rp_fitness).*

The fitness value of the sensor nodes is shared with the source node using the reply packets. The route selection function is modified to select the node with a high fitness value and the routing table is modified accordingly.

4.2. SIMULATION RESULT AND ANALYSIS

The presentation of obtained results from simulation on different scenarios is discussed in this section. In the area of 1000 x1000 m and a network of 50 nodes, the secure model is implemented.

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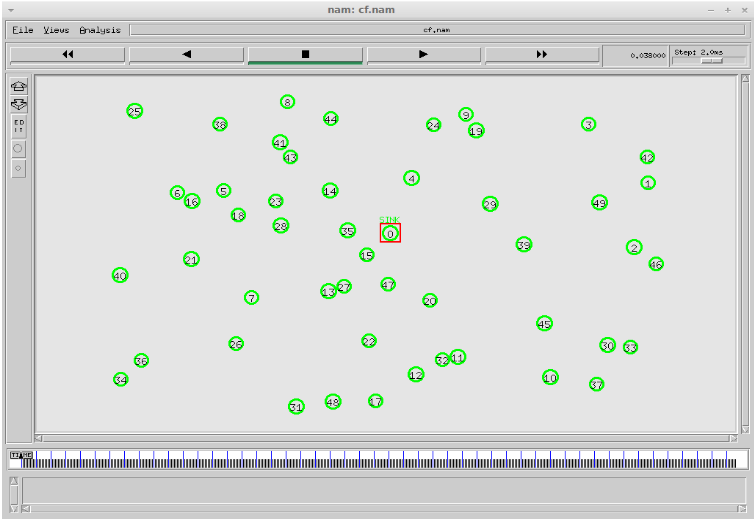

Figure 3. Network deployment

In the above Figure 3, the deployment of sensor nodes exists in the network with an area size of 1000x1000 randomly. The nodes are assigned with 100 joules of energy. The deployment of nodes is made in a random direction. At the network's center, the BS node is located for easier access. All the sensor nodes in the simulation area are assigned with unique node_id from 1 to n for unique identification.

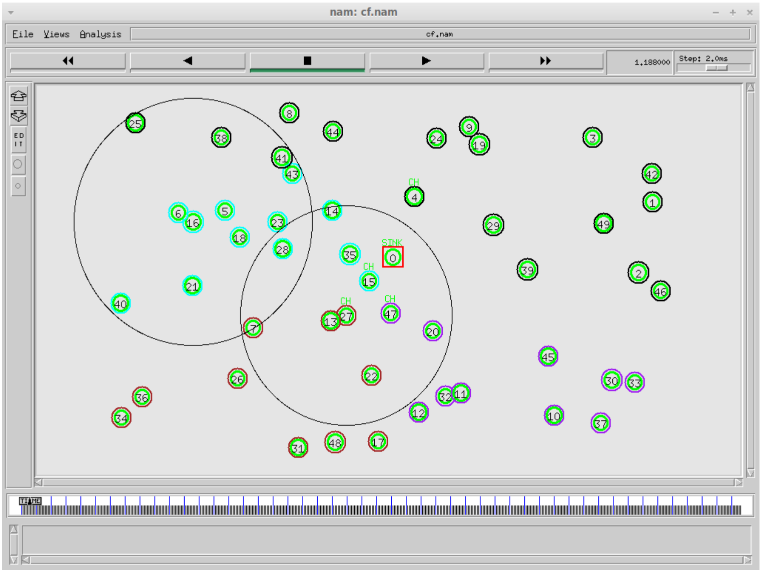

Figure 4. Clustering process

Clustering and sharing of control packets are presented in Figure 4. The network divides into 4 clusters and these clusters are associated with their respective CHs. The CH selection values are shared with the neighbor nodes using the broadcasting of control packets.

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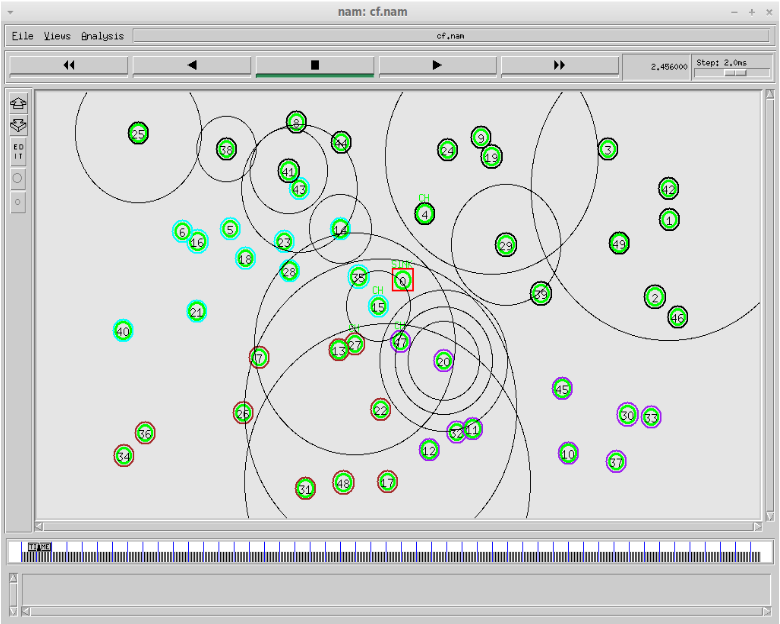

Figure 5. Broadcasting at Cluster heads

In Figure 5, the broadcasting process at cluster heads is described. The member nodes look for the optimal relays by broadcasting the control packets (shown as black circles in the screenshot.

Nodes broadcast the control packets repeatedly until the destination node is found or until the expiration time). The sensor nodes start transferring the data packets to their respective CHs. The forwarder node selection is enhanced by modified gravitational search algorithm and the data packets are transferred to the respective CHs using the selected forwarder nodes.

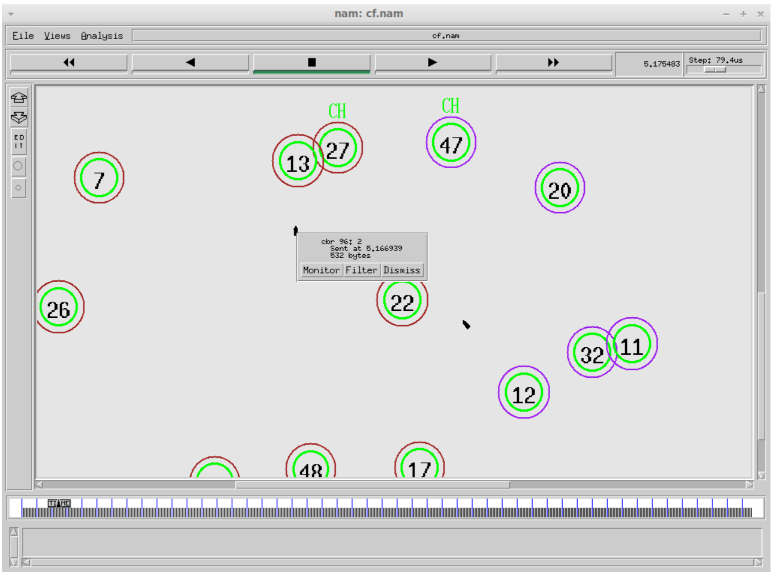

Figure 6. Data communication between sensor nodes and CH's

In above Figure 6, data communication between sensor nodes and CH's is shown in which the data unit size transferred between the sensor nodes and CH is 532 bytes. The CHs aggregates the data from their respective cluster members and share the data to the BS at particular intervals.

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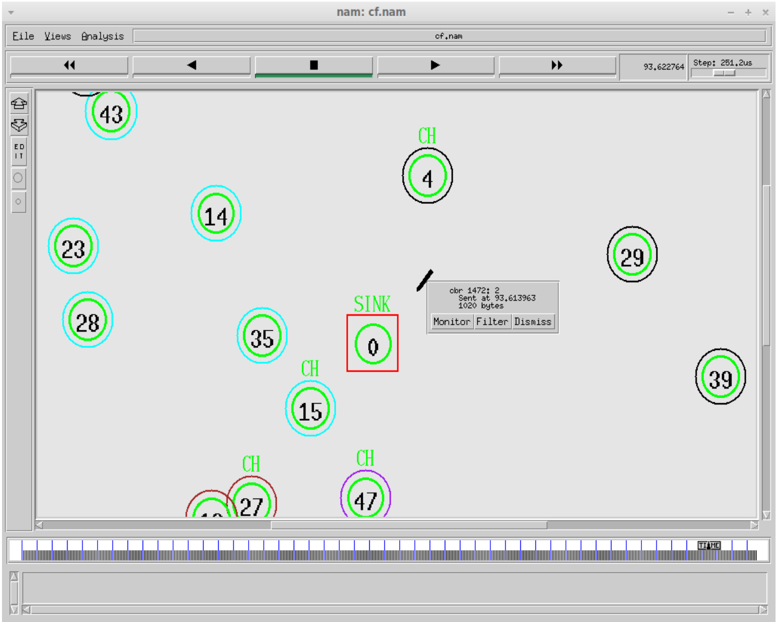

Figure 7. Data process between CH's and BS node

Figure 7 is mentioned about the process of data between BS node and CH's. The transmission of information to BS by CH nodes is carried out after aggregation from sensor nodes. If there is no direct connectivity between CH and BS due to long distance, then the modified GSA finds the best forward nodes and establishes the route between them.

```
Cluster - 1 : 7 13 17 22 26 27 31 34 36 48
Cluster - 2 : 10 11 12 20 30 32 33 37 45 47
Cluster - 3 : 5 6 14 15 16 18 21 23 28 35 40 43
Cluster - 4 : 1 2 3 4 8 9 19 24 25 29 38 39 41 42 44 46 49
```

Figure 8. Cluster file

Cluster file is presented in above Figure 8. Cluster formation after broadcasting of control packets among the nodes. The overall network categorizes into four clusters. Each cluster having unequal number of member nodes of their respective locations in the network area.

```
SINK: 0 SINK X_pos: 511 SINK Y_pos : 344 Node X_pos : 427 Node Y_pos: 244
Distance from node 27 to SINK  0
DIST: 130.598622  PROBABILITY VALUE: 0.001258
RES.ENERGY: 98.880130

SINK: 0 SINK X_pos: 511 SINK Y_pos : 344 Node X_pos : 341 Node Y_pos: 16
Distance from node 31 to SINK  0
DIST: 369.437410  PROBABILITY VALUE: 0.585115
RES.ENERGY: 99.073502

SINK: 0 SINK X_pos: 511 SINK Y_pos : 344 Node X_pos : 25 Node Y_pos: 68
Distance from node 34 to SINK  0
DIST: 558.902496  PROBABILITY VALUE: 0.235653
RES.ENERGY: 99.325084

SINK: 0 SINK X_pos: 511 SINK Y_pos : 344 Node X_pos : 61 Node Y_pos: 103
Distance from node 36 to SINK  0
DIST: 510.471351  PROBABILITY VALUE: 0.103633
RES.ENERGY: 99.260817

SINK: 0 SINK X_pos: 511 SINK Y_pos : 344 Node X_pos : 408 Node Y_pos: 25
Distance from node 48 to SINK  0
DIST: 335.216348  PROBABILITY VALUE: 0.896038
RES.ENERGY: 99.029993


Cluster Head(CH) is node : 27
```


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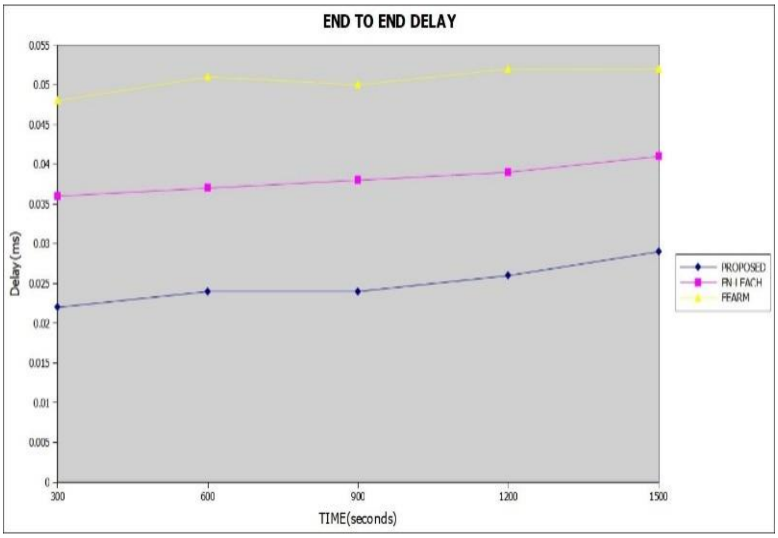
Figure 9. Multi-objective parameters file

Figure 9 is discussing the multi-objective parameters file. Multi-objective parameters like distance to BS, residual energy and node probability value are considered for CH selection. After clustering, every node in the cluster shares these details to the remaining nodes within the clusters and based on the shared values CHs are selected for each cluster.



TIME	PROPOSAL	EN-LEACH	FEARM
300	0.022	0.036	0.048
600	0.024	0.037	0.051
900	0.024	0.036	0.05
1200	0.026	0.039	0.052
1500	0.029	0.041	0.052

Figure 10. Performance on Delay

The end-to-end delay defines the efficiency of the network. Higher delay affects the overall network performance. Performance on Delay is shown in Figure 10. The MGSA selects the forwarder nodes based on multi-objective parameters and estimation of distance between the nodes is the major parameter which reduces the end-to-end delay while transmission of data. The results of simulation prove that the delay is comparatively lesser than the previously used protocols.

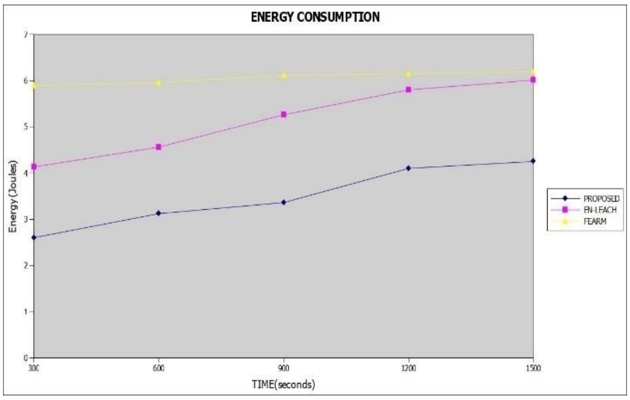


Figure 11. Energy consumption

TIME	PROPOSED	EN-LEACH	FEARM
300	2.6	4.13	5.89
600	3.12	4.56	5.96
900	3.36	5.26	6.11

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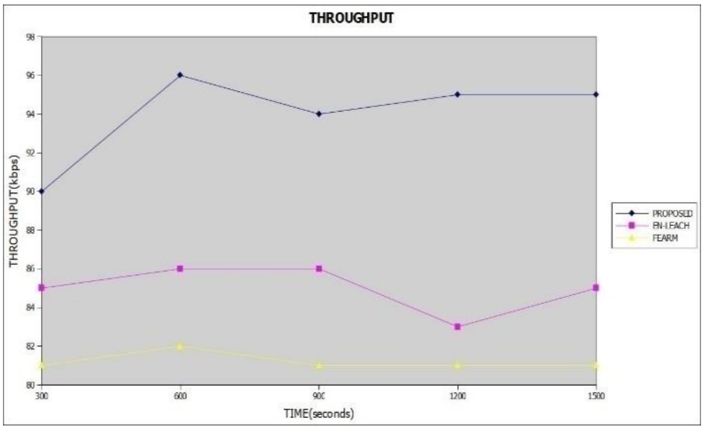
1200	4.1	5.8	6.15
1500	4.25	6.01	6.19

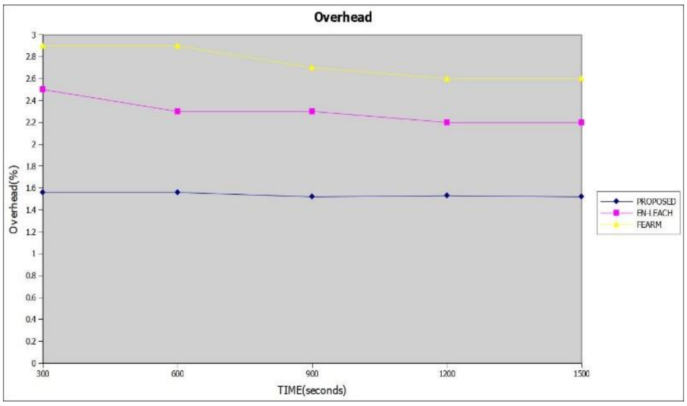
Energy is the vital factor for the sensor nodes for participating in network activities. The minimum energy consumption will lead to the prolonged lifetime of a network. Major energy consumption happens during data transmission. The MGSA forwarder node selection decreases the conservation of energy by proper forwarder node selection. Figure 11 is illustrated the results of energy consumption which proves that the proposed algorithm optimizes the consumption of energy than other protocols.



TIME	PROPOSAL	EN-LEACH	FEARM
300	90	85	81
600	96	86	82
900	94	86	82
1200	95	83	82
1500	95	85	81

Figure 12. Throughput

Throughput defines the successful data delivery rate. Various factors affect the data transmission often and these can be avoided by efficient forwarder node selection process. The MGSA-ORS algorithm selects forwarder nodes based on multi-objective criteria which help to deliver the data with less delay. Figure 12 is shown the graphs of throughput which proves that the proposed MGSA-ORS algorithm delivers data successfully than the previous protocols.



TIME	PROPOSAL	EN-LEACH	FEARM
300	1.56	2.5	2.9
600	1.56	2.3	2.9
900	1.52	2.3	2.7
1200	1.53	2.2	2.6

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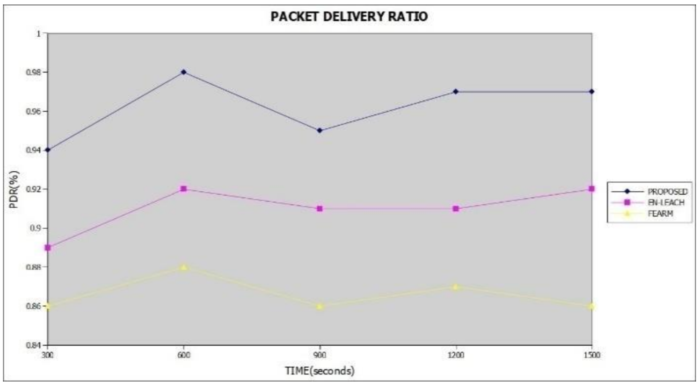
1500	1.52	2.2	2.6

Figure 13. Routing overhead

Overhead defines the amount of complexity the network experienced to process these algorithms. Less overhead yield good results to the network. The use of MGSA and the data aggregation using the MGSA selected forwarder nodes reduces the routing complexity. Figure 13 is describes the routing overhead results where the CH selection is also decided by the distance to BS parameter which further reduces the communication overhead between CH and BS.



TIME	PROPOSAL	EN-LEACH	FEARM
300	0.94	0.89	0.86
600	0.98	0.92	0.88
900	0.95	0.91	0.86
1200	0.97	0.91	0.87
1500	0.97	0.92	0.86

Figure 14. Packet delivery ratio

PDR defines the ratio of successful data deliveries over time. Improper forwarder node selection often affects the PDR due to delay and packet drops. The MGSA-ORS alleviates this and selects the forwarder nodes with sufficient capacity to transfer the data. Figure 14 is presented the simulation results of packet delivery ratio and it shows that the PDR value is higher than the previously proposed algorithms.

5. CONCLUSION

Providing energy-aware CH selection and optimal relay node selection algorithm using multi-objective CH selection and modified gravitational search method to choose the optimal routes propose in the paper. The important advantage of MGSA is using the multi-objective parameters for route discovery and the efficient route is chosen with the help of node distance to CHs, energy, and delay of the sensor nodes. CH selection is optimized using the multi-objective parameters like distance to BS, residual energy, and probability value. The simulation results prove that the proposed multi-objective MGSA-ORS method achieves high energy efficiency with less overhead to the network. Because of CHs selection by the distance between nodes and BS approach, the improved throughput and data delivery rate have been achieved for inter-cluster data aggregation. The use of MGSA achieves high efficiency with the inclusion of multi-objective parameters. The proposed MGSA-ORS is outperformed all the major energy-efficient routing protocols in every possible way by assessing the experimental results.

Even though our proposed mechanism selects reliable Cluster heads, CH failure is inevitable in energy-constrained, clustered WSNs. So, this work can be further extended to improve CH reliability and providing fault-tolerance with optimized energy consumption.

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