ZKG INTERNATIONAL
ISSN: 2366-1313

Improving the energy efficiency in Wireless Sensor Networks using best relay selection Approach

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Abstract:
In WSNs, achieving energy efficiency is a laborious process. It is imperative to find efficient and dependable solutions to the energy shortage and consumption issues. Clustering is a useful method for wireless sensor networks (WSNs) to conserve energy. The majority of clustering algorithms cluster the network and choose CH for simple cluster administration. The fundamental issue with these clustering algorithms, however, is that they all have some drawbacks and take a long time to execute in big networks, which adds to the overhead of the network. The best relay node selection is essential to maximising energy savings since poor node selection results in excessive energy use in sensor nodes. Therefore, it is necessary to create a combination method that enhances the clustering and the best relay node selection procedures. Here, we provide MGSA-ORS (Modified Gravitational Search algorithm for optimal relay node selection), a new energy efficiency management technique. This algorithm chooses CHs depending on a number of factors, including the proximity of the sensor node to the SINK, the remaining energy, and the probability value. By taking into account the distance between sensor nodes and SINK, excessive energy consumption is prevented. Additionally, the proposed MGSA uses residual energy and link delay as well as each node's distance from its respective CHs as the primary criteria for selecting relay nodes. The simulation results demonstrate that the suggested energy efficiency algorithm improves network lifespan data delivery rate and achieves greater energy efficiency than earlier published algorithms like LEACH.
Keywords: WSN, Cluster head selection, Gravitational Search Algorithm, Relay node selection, LEACH, Energy efficiency, Network lifetime.

I. INTRODUCTION

WSNs—wireless sensor networks—play a significant role inthe term wireless communication. They are useful for manyapplications, such as healthcare applications, civil applications,and military applications. Wireless sensor networks includenodes that have the ability to sense

ISSN: 2366-1313

humidity, temperaturelevel, and conditions of pressure. They can also gatherinformation of the physical area then process and transferthem to the base station (BS) [1].

Wireless sensor and actor network (WSAN) is a group ofsensors and actors where a sensor node collects data bysensing operation and actors perform appropriate actions by processing the received data [2–5]. Sensor nodes havelimited resources, such as battery, processing capability,transmission power, and limited wireless communicationcapabilities. However, actor nodes are resource rich nodes [2, 3]. In a wireless sensor and actor network, efficientdecision-making for routing and execution of tasks aremajor challenges. Timely data delivery at an actor node is amajor issue in a WSAN for applications like activating watersprinkler and alarm in fire accident, battlefield surveillance,biological and chemical attack detection, home automation,and environmental monitoring [2–8].

Energy efficiency and reliability in data collection aremajor issues in WSANs. In WSANs, a data collectionprotocol may satisfy the major application requirements,such as high data reliability and less delay along with energyefficiency. These requirements can be achieved by designingan energy efficient intelligent routing protocol. The sensornodes may be deployed randomly in a dynamic environment[9]. This results in dropping of packets due to dynamicchanges in quality of wireless links. The major reasons fordropping of packets may be bad wireless link quality andunavailability of free buffer at intermediate nodes and residualenergy at nodes. To ensure data reliability, thedropped packets need to be retransmitted, and this leads tomore delay and energy consumption. Therefore, an energyefficient routing protocol may solve the above issues bytaking efficient routing decisions while considering energy ofa node, link quality, and available buffer.

WSNs are figured to play a dominant role in the IoT paradigms.The resilience, autonomous, and energy-efficient traitsof WSNs render them a vital candidate for dominating theinformation collection task of an IoT framework [10].

Only the cluster head (CH) in the network is allowed totake the information exchanged by a sensor node, in whichCH transfers the BS aggregated data. This aggregation of dataof sensor node happens in CH due to its important fusion rolethat decreases the data sent to the BS and thus saves energyand bandwidth resources. But, clustering can be crucial informing the network to thousands and hundreds. The clusteralso plays a role in organizing applications, so it is for manyapplications a natural method to combine sensor nodes that arespatially closed to take advantage of correlations and minimizethe revealed redundancy in the readings of the sensor [11].

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However, applying the multi-hop routing technique willsurely lead to weighty overhead for network topology managingand medium access control. Direct one-hop routing will bemore effective if the whole sensor nodes were very close to thesink node [12].

However, the portion of a CH in other cluster-based trackprotocol focuses on a single area which makes them unsuitablefor critical applications that need time. Hence, somecluster-based track protocol provides a space for every CHto forward aggregated data to base stations which decreasesthe energy consumption [13].

Many works are so far proposed towards minimization of energy usage. One of the ways to minimize such energy usage is employment of clustering scheme. Clustering is defined as the grouping of similar objects or the process of finding a natural association among some specific objects or data. It is used in WSN to transmit processed data to base station minimizing the number of nodes that take part in long distance communication leading to lowering of total energy consumption of the system. Clustering and multi-hop routing is the common approach to improve energy efficiency of the network. Instead of letting each node in the network forward its own information to the base station directly, they are grouped into different clusters. In each cluster, a cluster head (CH) node is selected based on some criteria. The CH node will collect information from other cluster member nodes and then forward the processed information to base station using other CH nodes via multiple hops. The benefit of such scheme is twofold. First, the CH node can compress the data collected from cluster member nodes to reduce unwanted redundancy. Second, the energy efficiency is greatly improved by letting most nodes in the network transmit to a nearby CH node, and limiting the multiple hop communication to CH nodes only.

The rest of this paper is organized as follows. In section 2, some of the recent researches about energy efficient Clustering protocols in wireless sensor networks are presented. In section 3, the proposed approach is described. Section 4 represents the simulation parameters and discusses about the simulation results and finally section 5 concludes the paper.

II. LITERATURE SURVEY

Rout et al. [14] have estimated the energyconsumptions for tree-based rechargeable sensor networks.In[15], upper bounds on the network lifetime have beenestimated by considering the duty cycle and networkcoding.

Neamatollahi et al. [16] have proposed a fuzzy-basedhyper round policy mechanism to mitigate the reclusteringoverhead problem in a WSN. In [17], a cluster head selectionpolicy based on the fuzzy logic and particle swarm optimizationhas been proposed for a WSN to improve thelifetime. In [18], a fuzzy-based unequal clusteringmechanism has been designed for

ISSN: 2366-1313

addressing the hotspotproblem in a WSN by proper selection of cluster head andunequal cluster formation. However, in our work, we haveproposed a delay and energy-aware routing protocol for aheterogeneous sensor actor network using the fuzzy logicsystem under variable network states.

Pantazis et al. [19] have presented a survey on energyefficient routing protocols in a wireless sensor network. In[20], cost of a path has been computed in terms of number oflink layer transmissions by considering the link quality andrelative ordering of the links for a wireless mesh network. Anetwork coding-based probabilistic routing protocol hasbeen proposed for a cluster-based WSN by Rout et al. [21].

Zhang et al. [22] have proposed an energy balanced routingprotocol where the next node is selected based on the linkweight and the forward energy density. In [23], an opportunisticrouting protocol has been proposed for a duty cycledWSN where residual energy is considered with a forwarder selection algorithm. Sun et al.[24] have proposed an ant colony optimization-basedrouting algorithm by considering the node's communicationtransmission distance, the transmission direction, andthe residual energy. However, in our work, an energy-awarerouting metric (i.e., a routing parameter) has been proposedto take the efficient routing decisions by considering theresidual energy, the quality of the link, the available freebuffer, and the distance.

Sindhwani and Vaid (2013) addressed a vice cluster headlow energy adaptive clustering hierarchy which enhances thedifficulty in the LEACH protocol by giving a vice cluster headto each cluster which plays the function of the cluster headwhen the cluster head is damaged; this minimizes the highamount of selecting a new cluster head each time when acluster head is damaged and the data will always be obtainedby the base station and enlarge a network lifetime [25].

Liao and Zhu (2013) showed that an energy-balanced clusteringalgorithm based on the LEACH protocol relies on theremaining energy and distance agents, which improves thestrategies of selection and not the selection of the cluster headalong with the optimal cluster head selection [26].

Bakaraniya and Mehta (2013) presented K-LEACH to enhancethe sensor network lifetime by normal clusteringthrough a k-medoids algorithm and scale the capacity of theentire network among all the active nodes. It assures by givingnormal clustering of nodes that is provided with the suitableplace of CH. It uses the clustering union, maximum remainingenergy criterion, and the choice of CHs only after almost 50%of round operations randomly of the network, whereas theLEACH protocol provides a totally random selection ofCHs, which leads to a very poor choice of CHs and consequentlyleads to a high degree of lifetime reduction and energymaintenance by the network [27].

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Kole et al. (2014) discussed the distance-based cluster formationimproves the LEACH protocol in enlarging the lifetimeof the network. The distance of the node from the basestation is important in forming the cluster that will reduceother transference in the current LEACH protocol [28].

[Sai Krishna Mothku, Rashmi Ranjan Rout) In this paper, a fuzzy-based delay and energy-aware intelligent routing mechanism has been proposed to select efficientroutes. In the proposed mechanism, routing decisions are taken using a fuzzy logic system by considering network resources, suchas residual energy, quality of link, available buffer size, and distance (proximity). In a network, a node with higher residual energy,higher free available buffer, good link quality, and close distance (proximity) gets opportunity to become a next hop node in arouting path [29].

[Amer O.Abu Salem, Noor Shudifat] Therefore, theaim of this paper is to overcome these limitations through enhancing the LEACH (low energy adaptive clustering hierarchy)protocol, the protocol of cluster routing, in which, LEACH is extended by identifying a cluster head according to the lowestdegree of distance from the base station in order to decrease power consumption in cluster head nodes and in the whole network.Hence, the results clarify the ability of LEACH in enhancing the network lifetime as well as in reducing and minimizing the consumption of power [30].

III. Proposed framework

The Proposed Protocol (MGSA-ORS) in detail described in below and comparison with existing methods as FEARM [29] and [ELEACH] [30].

The proposed MGSA-ORS is an energy efficient cluster based protocol that distributes energy load evenly among all sensor units in the network. It is characterized by 1) Cluster head selection based on residual energy and the distance between the node and SINK 2) Multi-hop intra and inter cluster communication that chooses a multi-hop path with minimum communication cost using MGSA from each node to CHs.

Only the nodes with higher residual energy and minimum distance to SINK node become cluster heads. Cluster members send data directly to the cluster head. Cluster head aggregates the data and transmit to the base station through the multi-hop routing paths. Node distance from SINK is the major selection parameter here. Thus the overhead of inter cluster communication is minimized for cluster heads near the base station which will prevent them from dying soon. Also nodes send data through the path with minimum communication cost which reduces cost per data packet. All these factors prolong the network lifetime and improves the energy efficiency.

The operation of MGSA-ORS is broken in to rounds where each round consists of 2 phases:

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- Set-up phase and
- Steady state phase.

In the set-up phase, clusters are organized and multi-hop path is chosen from each cluster member to the CHs and to the base station. The data transmission takes place in the steady state phase. To minimize network overhead, steady state phase is longer than set-up phase.

Set-up phase:

The set-up phase involves the following phases:

- Cluster-head selection
- Cluster formation

During the set-up phase, cluster heads are selected, clusters are formed and multi-hop path from each cluster head to the base station is chosen.

Cluster Head Selection:

At the beginning of set-up phase, each node estimate their distance from the SINK node and share the distance information and residual energy details to the neighbour nodes. A probability value us calculated for every nodes using the random value between 0 and 1.

The distance between the node and SINK is calculated using Euclidean distance as follows in equation (1)

$$Dist = \sqrt[2]{(xpos_{sink} - xpos_{node})^2 + (ypos_{sink} - ypos_{node})^2} \quad (1)$$

Where $xpos_{sink}$&$xpos_{node}$ are the x position of the sink and node and $ypos_{sink}$&$ypos_{node}$ are the y position of the sink and node respectively.

The residual energy can be calculated as follows in equation (2):

$$RE = E_{initial} - E_{consumed} \quad (2)$$

Where$E_{initial}$ is the initial energy of the sensor nodes.

The node become the CH when the distance to the SINK is minimum and the residual energy is higher than the rest of the nodes.

Cluster formation:

Once cluster heads are selected, base station sends CH_ADV (cluster head advertisement) message to its neighbours which are then propagated outwards by cluster heads. From the CH_ADV messages received, each member node chooses the nearest cluster head based on the

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signal strength of received CH_ADV messages. If direct communication cost to base station is less when there is no cluster head is to join for a sensor node, then the node sends data directly to the base station. Otherwise it decides to join the cluster with nearest cluster head. Once each node decides the cluster in which it belongs to, the node sends JOIN message to the cluster head. When cluster head receives JOIN message from all nodes that would like to join the cluster, it creates a communication schedule and broadcast the schedule to all member nodes. Thus clusters are organized.

Steady state phase

Data transmission occurs in the steady state phase. Both intra and inter cluster communication occurs in the network using multi-hop paths. Here we introduce MGSA as optimal relay node selection algorithm that chose the relay nodes for the data transmission based modified gravitational search approach.

Gravitational Search Approach (GSA) is a population based search algorithm based on that each factor in each iteration experiences three steps. The first step is called adjustment in which the efficiency and influence of the factor is adjusted. The second step is cooperation that the factors cooperation with each other is identified and the third step is competition that the factors compete
with each other for more lifetime. In this paper the GSA is used for searching the best route based on distance to CH, residual energy and minimum delay.

Gravitational search algorithm

Inspired from the law of gravitation and the law of motion, a stochastic optimization algorithm called GSA is developed. By Newton's universal law of gravitation, "objects in the universe attract each other with a force (F) which is directly proportional to the product of their masses (M1 and M2) and inversely proportional to the square of distance between them" as follows in equation (3):

$$F = G\frac{M1 . M2}{R^2} \quad (3)$$

Where G denotes the gravitational constant and R denotes the Euclidean distance between M1 and M2.

The law of motion gives a relationship between an object's mass M, its acceleration a, and the force F applied on it as follows in equation (4):

$$a = \frac{F}{M} \quad (4)$$

Acceleration will be small for large masses and vice versa. GSA combines both these laws and considers every object as an agent having a position, velocity, acceleration, and mass. Hence, according to GSA, agents attract each other by gravitational force of attraction and the smaller

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(lighter) agents move with a higher acceleration towards the bigger (heavier) ones. Eventually, all agents will get attracted towards the heaviest agent. The performance of an agent is measured by its mass. Heavy mass represents an optimal solution for the given problem.

The basic GSA algorithm is defined with the following phases

- Population initialization

In this phase, the initial positions of the agents at time t is populated as follows equation (5)

$$X_i(t) = (x_1, x_2, \dots \dots \dots . x_n) \quad (5)$$

- Fitness evaluation

Evaluate the fitness function at each agent location. For a minimization problem, the best fitness value will be the least among the fitness values of all agents and worst value will be the highest one.

$$best_t = \min fit(t)$$
$$worst_t = \max fit(t)$$

- Update & calculations

Based on the calculated fitness values, agents force, mass, and velocity are updated.

Modified GSA algorithm

In this paper, the selection of the optimal relay nodes from the sensor nodes in the WSN depends on the proposed Multi-objective Fitness function. The MGSA proposes the maximization fitness function based on the various objectives, such as delay, distance to CHs, and the energy of the nodes. To select the sensor node as the relay head, each node satisfies the fitness function providing the maximum value. The following equation (6) expresses the proposed Multi-objective Fitness function.

$$fitness(n) = \{ Dist_{n-CH} + E_{res}(n) + D(n) \} (6)$$

Where, $Dist_{n-CH}$ indicates the distance of the node n from the respective CH, $E_{res}(n)$ indicates the residual energy of the node n and $D(n)$ indicates the total normalized delay of the sensor node n. The multi-objectives in the fitness function is explained as follows,

Delay: Delay of the WSN defines the sum of the delay present in each node of the WSN. To select the node as an optimal relay, the delay should be as low as possible. The delay of the node directly depends on the following parameters

- expected transmission count (ETC) of the node,
- propagation delay of the node, and
- The transmission delay of the network.

The equation (7) expresses the delay of the nodes in the WSN.

$$D(t) = \sum_{i=1}^{n} ETC_n (TD + PD_n) (7)$$

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Where, ETC_n indicates the expected transmission count (ETC) of the node n, TD is the total transmission of the whole network and PD_n is the propagation delay at node n.

Distance to CHs: The second objective of the fitness function is the distance between the nodes and the cluster heads. For the effective communication, the distance between the sensor nodes and the cluster heads should be low. The following equation (8) expresses the distance between the nodes and the cluster head

$$DIST = \sqrt[2]{(xpos_{CH} - xpos_{node})^2 + (ypos_{CH} - ypos_{node})^2} \quad (8)$$

Where $xpos_{CH}$&$xpos_{node}$ are the x position of the CH and node and $ypos_{CH}$&$ypos_{node}$ are the y position of the CH and node respectively.

Energy*:* The energy of the nodes should be high to select the node as the cluster head. The residual energy of the nodes in the WSN is expressed as per equation (2).

Based on the evaluation of these multi objective parameters the optimal relay nodes are selected for routing process.

IV. Result and discussion

Experimental setup

To assess the proposed method's performance, the simulation is conducted by comparing with two different schemes. NS2 or network simulator 2 has been used in this project and it is an object oriented and discrete event driven network simulator that targets at 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 same radio-transmitter devices, same capabilities, and constrained power resources, having same initial energy, and uniform deployment. The BS is fixed and located away from the sensor node. Based on the 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 nodes initial energy is used up. In the below table (Table 1), the simulation parameters are considered.

PARAMETER	**VALUE**
Application traffic	CBR
Transmission rate	1024 bytes/ 1ms
Radio range	250m
Packet length	1024 bytes

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Routing Protocol	AODV
Simulation time	100s
Number of nodes	50
Area	1000 x1000
Routing methods	MGSA-ORS, FEARM [29], ELEACH [30]
Transmission Protocol	UDP
Initial Energy	100j

Table1: Simulation table

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 attack model is implemented.

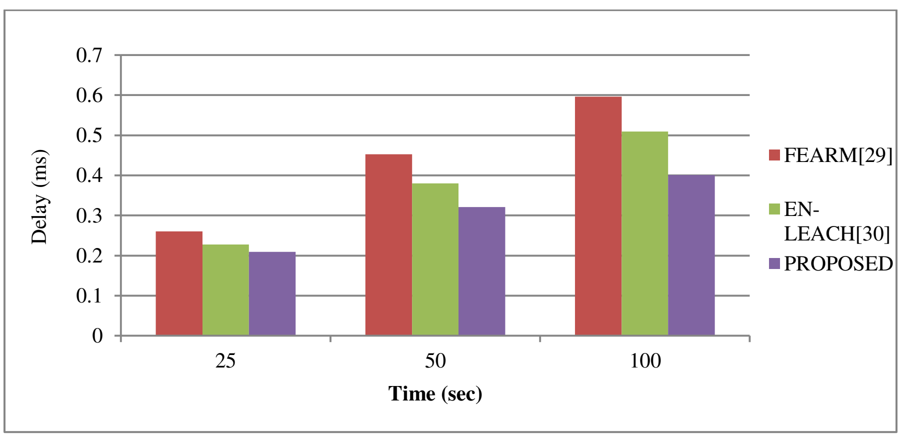

Fig.1: Performance on Delay

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 1. 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 during data transmission. The results of simulation proves that the delay is comparatively lesser than the previously used protocols.

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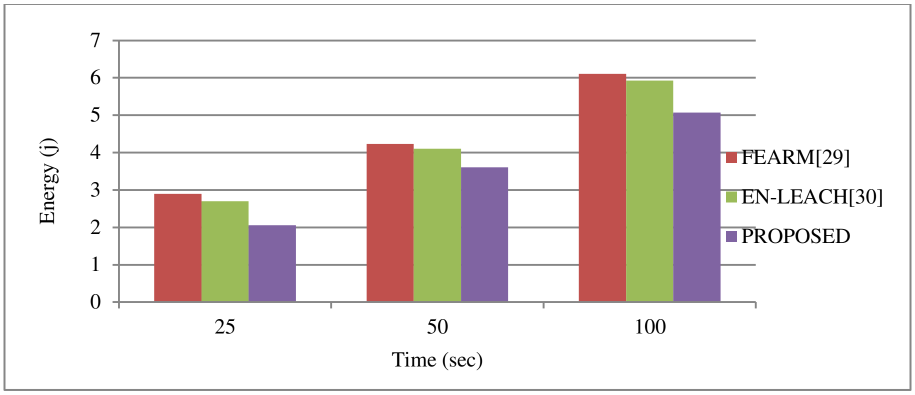

Fig.2: Energy consumption

Energy is the vital factor for the sensor nodes to participate 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 2 is illustrated the results of energy consumption which proves that the proposed algorithm optimizes the consumption of energy than other protocols.

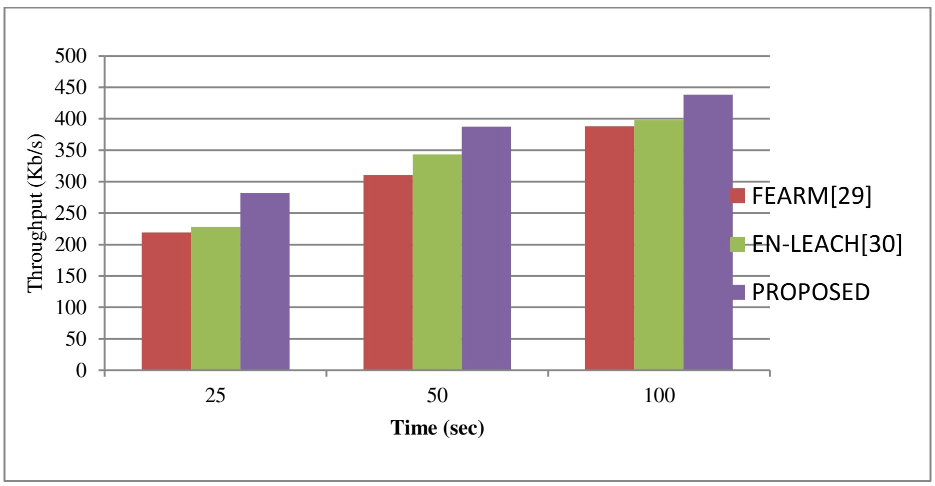

Fig.3: Throughput

Throughput defines the successful data delivery rate. Various factors affects 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 helps to deliver the data with less delay. Figure 3 is shown the graphs of throughput which proves that the proposed MGSA-ORS algorithm delivers data successfully than the previous protocols.

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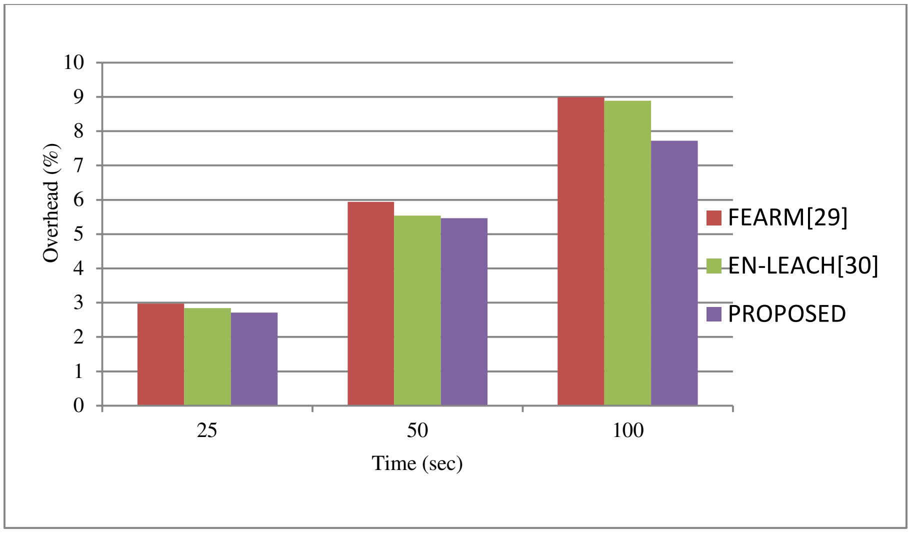

Fig.4: Routing overhead

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 4 is describes the routing overhead results where the CH selection is also decided by the distance to SINK parameter which further reduces the communication overhead between CH and SINK.

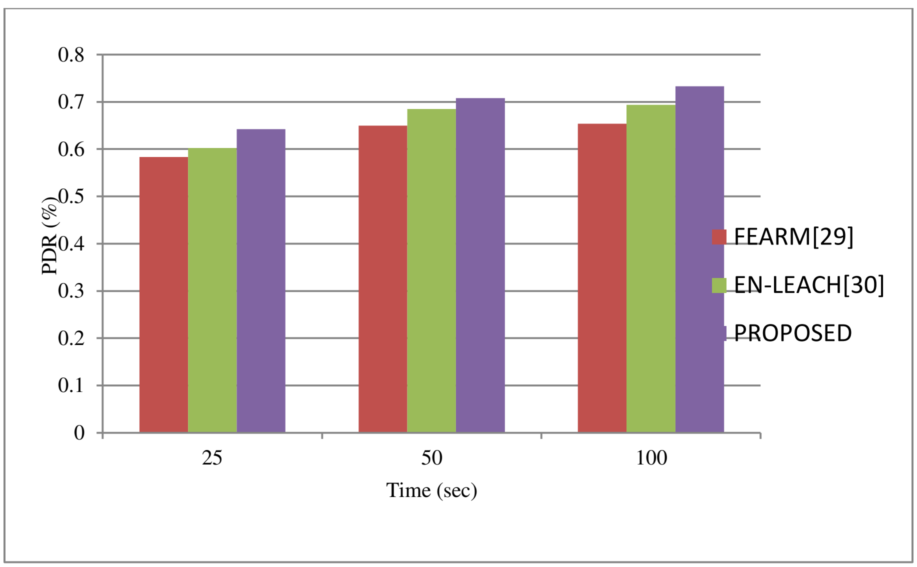

Fig.5: Packet delivery ratio

PDR defines the ratio of successful data deliveries over the 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 5 is presented the simulation results of packet delivery ratio and it shows that the PDR value is higher than the previously proposed algorithms.

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Conclusion

In this research, a multi-objective CH selection algorithm with an energy-aware CH selection and a modified gravitational search approach for choosing the best routes are proposed. The key benefit of MGSA is the use of many objective factors for route discovery and choosing the optimum route based on the sensor node distance from CHs, energy, and latency. Multi-objective criteria including the distance to the SINK, the remaining energy, and the probability value are used to optimise the choice of CH. The outcomes of the simulation show that the multi-objective MGSA-ORS technique can achieve great energy efficiency with minimal network overhead. Additionally, the results demonstrate that the selection of CHs based on the distance between nodes and SINK technique increased the data delivery rate and throughput for inter-cluster data aggregation. The usage of multi objective parameters along with MGSA results in excellent efficiency. The evidence from the experiments shows that the suggested MGSA-ORS performs better than all the major energy-efficient routing protocols in every regard.

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