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Enhanced LEACH protocol for increasing a lifetime of WSNs

S Praveen Kumar, Assistant Professor of ECE, JNTUH College of Engineering Jagtial,
praveenkumar_00019@yahoo.com

Abstract:
Energy efficiency is a laborious feat to accomplish. Limited energy resources and their usage is a key issue which requires attention by offering practical and productive answers to mitigate it. Clustering is a profitable strategy to preserve energy in wireless sensor networks (WSNs). The network is clustered by almost all clustering algorithms and the CH (cluster head) is chosen for simple control of the clusters. Although, a key drawback in all the clustering algorithms is that there are particular constraints and the duration of processing is long, thereby leading to higher miscellaneous network costs. Optimal relay node selection is crucial task to save more energy as improper node selection leads to unnecessary energy utilization in sensor nodes. To conserve more energy, Optimal relay node selection is a key process, as a wrong node choice can result in needless energy consumption in the sensor nodes. Hence, arises a requirement of a merged algorithm that brings out the best in clustering and optimal relay node selection techniques both. In this work, we present a novel energy efficiency control algorithm, MFF-ORS (Modified Fitness Function for optimal relay node selection). The program chooses CHs according to several methods such as the SINK-adjacent sensor node, residual energy and probability value. The sensor node adjacence to the SINK is considered since the energy consumption of the needles decreases due to the distance between nodes. Each node adjacence to the respective cluster heads and residual energy and the link time is taken in consideration in the MFFA given. According to the computer modelling outcomes, the presented algorithm accomplishes higher energy efficiency in comparison to past algorithms like LEACH and enhances the rate of data processing.

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

INTRODUCTION

A key part is contributed to the field of wireless communication by WSNs-wireless sensor networks. It is widely applicable in the fields of healthcare, military, and many more. These networks comprise of nodes having the facility to perceive humidity, temperature, and pressure. In addition, they can transfer the information after processing from its physical location to its base station (BS) [1].

A set of sensors and participants called Wireless sensor and actor network in which a sensor node obtains data with the help of its sensing ability and the participants/actors work upon the data received [2–5]. Constraints associated with sensors are battery capacity, transmission power, processing potential and communication limits. On the other hand, actor nodes have many functionalities [2, 3]. Productive decision-making in a wireless sensor and player network for routing & performing jobs is a crucial issue. In crises and situations like home automation, fire accidents, biological and chemical attacks, prompt delivery of data is crucial in a WSAN [2–8].

In data receiving, energy efficiency is a key problem in WSANs. A protocol for receiving data in WSANs could meet key needs in applications like high data efficiency and low delays. Such needs can be satisfied by developing an intelligent routing system that is energy efficient. The sensors can be placed in a changing environment arbitrarily [9]. As the quality of wireless connections is always changing, this results in a drop in the packet. Some reasons for dropping packets are poor quality of the wireless network and lack of publicly accessible buffer at intermediate nodes and residual energy. The packets lost are required to be retransmitted, resulting in more delays and energy usage, to improve data reliability. With the help of improved routing decision-making taking into consideration link quality, buffer and energy of node at disposal, an energy efficient routing protocol can hence solve the aforementioned problems.

In the IoT paradigms, WSNs are key players. They remain key players in the IoT framework, owing to attributes like resilience, autonomy, and energy efficiency [10].

In the network, the cluster head has the exclusive rights to obtain the information sent out by the nodes, upon which the CH combines the data and sends it to the BS. CH reduces the amount of data transferred to BS through its fusion role, therefore preserving bandwidth and energy resources. Although, it can play a key role in forming networks with thousands of sensor nodes. It also helps with organizing by combining sensor nodes adjacent to each other to bring out the best of correlations and decrease the repetition in the sensor results [11].

But, application of the multi-hop routing method could definitely result in high overload for network topology management and medium access control. A better method is Direct one-hop routing in the case when whole sensor nodes are near the sink node [12].

Although, a single area is targeted by a segment of a CH in other cluster-based track protocol which renders them unusable for key applications requiring time. This allows all CHs to transfer aggregated information to B.S., decreasing energy usage[13], through a cluster-based track protocol.

A majority of works presented till now are centred around the idea of energy conservation. A method to conserve energy is the application of clustering scheme. According to the definition, clustering is the grouping of identical objects or the technique of spotting a relation between particular objects. In WSN, it is applied when transmitted data is sent to BS thus reducing the number of nodes participating in long-distance communication thereby decreasing total energy usage of system. To enhance energy efficiency of a network, clustering and multi-hop routing are widely used approaches. The nodes are put into various clusters instead of each node transmitting information to the BS directly. Depending on some conditions, for each cluster, a cluster head CH node is chosen. After obtaining data from other cluster group nodes, the CH node then relays this processed data to the BS with the help of other CH nodes through multiple hops. There are two advantages of this arrangement. One is that after obtaining data from other cluster nodes, the CH node compresses it to decrease needless redundancy. Also, by permitting nodes in the network to send data to an adjacent CH node, the energy efficiency is enhanced, therefore only confining multiple hop communication to CH nodes.

The remaining work is classified into different sections. Section 2 sheds some light upon the studies and works in the field of energy efficient Clustering protocols in wireless sensor networks. The presented technique is defined and discussed in section 3. The computer modelling and its outcomes are discussed in section 4. At the end, section 5 is the conclusion.

LITERATURE SURVEY

In their work, Rout et al. [14] detailed how the energy uses for the rechargeable tree sensor networks were approximated. The highest limits [15] of the network life have been calculated by taking into account the duty cycle and network coding.

[16] Neamatollahi et al. In these papers, a fluffy, hyper-round policies technology was given to overcome the clustering overhead problem in a network of wireless sensors. In [17], a CH selection policy was developed for a wireless sensor network based on particle swarm optimisation and fuzzy logic. To tackle the hotspot issue in a WSN, in [18], The correct cluster head selection and disproportionate cluster arrangement generated a fluffy-backed unparalleled clustering approach. On the other hand, a delay and energy aware routing protocol was developed in this paper for a heterogeneous network of actors with the fuzzy logical system in switching network states.

A close study on energy-efficient routing methods was given by Pantazis et al.[19] in the network of wireless sensors. In [20] the cost of a path was determined, depending on the quantity of transmissions based on the quality of the link and liaison order for a wireless network. Rout et al.[21] have suggested to establish a cluster-based WSN network coding probabilistic routing protocol.

Zhang et al.[22] In this work, the following node was picked based on weight and energy density of forward energy in this energy-balanced routing protocol. In a dual-cycled WSN, an opportunist routing protocol is introduced in [23], and with a forwarder selection algorithm residual energy is taken into account. Sun et al. [24] introduced an optimization ant colony-based route algorithm, taking into account the communication distance, residual energy and the transmission direction of the node. Although, in this research, a new parameter, an energy-aware routing metric, is presented for effective decision-making in routing by taking into account the quality of link, free buffer available, residual energy and the proximity.

Sindhwani and Vaid (2013) propose a CH low energy-adaptive clustering hierarchy by designating a vice cluster head for every cluster, and making it a CH when the main CH is beyond repair. This proposal tackles the issue in LEACH protocol and decreases the time to select a new CH every time a CH is not functional and the information is delivered in a robust manner to the base station and thus increases network lifespan [25].

Liao and Zhu (2013) examined the potential of the LEACH protocol in the process of cluster-head selection and presented an enhanced clustering algorithm. It factors in location information and residual energy of nodes. It enhances the method of selection of threshold for each CH selection. The computer modelling results prove that this protocol is an improved version of LEACH as an improved lifespan of network is observed, node energy usage is balanced, and information transmission is robust.

K–LEACH is proposed by Bakaraniya and Mehta (2013) to extend its lifespan by normal clustering through the entire active network with a k-medoid method. The selection of cluster head is done with a basis in Euclidean distance and maximum residual energy [27].

Kole et al. (2014)'s work sheds light upon the distance-based cluster formation and how it enhances the LEACH protocol in prolonging lifespan of network. For the formation of the cluster, the proximity of node to base station is an important consideration as it decreases transference in LEACH protocol [28].

(The Route of the Rashan Sai Krishna Mothku) In order to find best routes, this work contains a fluid-based delay and intelligent energy-aware routing mechanism. According to the presented approach, factoring in residual energy, buffer size available, link quality, and proximity, routing decisions are taken with the help of a fuzzy logic system. For a node to be a next hop in a routing path, it should have more available buffer strong link quality, more proximity and more residual energy [29].

[Amer O.Abu Salem, Noor Shudifat] In this work, the goal is to improve LEACH protocol and handle its drawbacks. The LEACH protocol is improved upon by locating a cluster head closest to the BS as power usage is decreased. Therefore, according to the outcomes, it is demonstrated that the network lifetime is prolonged and power usage is minimized [30].

Proposed framework

A description of the MFF-ORS and comparison with current techniques like FEARM [29] and ELEACH [30] is provided in the following text.
The energy-efficient cluster protocol presented in this work is the MFF-ORS which disseminates energy load equitably to all sensors in the network. Selection of CH is based on residual energy and node proximity to SINK. 2) Using MFFA, select a multi-hop routing with little exchange between intra- and inter-cluster communications from any node to CHs.

The criteria for becoming a CH is that the node should have greater residual energy and minimal proximity to SINK node. The information from the node participants is sent straight to CH. After combining the data received, the CH sends information to the BS through multi-hop routing paths. A key metric observed is proximity of node to SINK. Hence, the communication between clusters is reduced in cases where the CHs are adjacent to the BS thereby prolonging their lifetime. In addition to this, the nodes transmit information via the path using little communication, hence cutting back on cost per data packet. These attributes enhance energy efficiency contribute to the lifespan of the network.

The functionality of MFF-ORS is exhibited in two phases:-

- Set-up phase
- Steady state phase.

A multihop path is chosen from the cluster node to the cluster heads after the cluster organization and then to the BS for the set-up phase (base station). The continuous phase is longer than the configuration phase to avoid overhead networks.

Set-up phase:
The set-up phase entails two steps:

- Cluster-head selection
- Cluster formation

Cluster Head Selection:

Initially in the set-up phase, after estimation of proximity to SINK node, the nodes exchange this proximity information along with residual energy data with other adjacent nodes. For each node, a probability value is deduced.
The proximity of node to SINK is computed with the help of Euclidian distance formula as shown below (1)

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

Here, $xpos_{sink}$ & $xpos_{node}$ are the corresponding x position of the sink and node while the $ypos_{sink}$ & $ypos_{node}$ are the corresponding y position of the sink and node.
The residual energy is determined with the help of the following equation (2):

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

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

For the node to be a CH, more residual energy should be available in relation to other nodes and a minimum of closeness to SINK.

Cluster formation:
After the selection of cluster heads, a message CH_ADV meaning cluster head advertisement is transmitted from base station to the adjacent nodes and relayed by cluster heads. Depending on the signal strength of the obtained CH_ADV messages, every node selects the most adjacent cluster head. In the case where communication from node to base station is less costly, then the node sends information straight to the Base Station. In other cases, node opts for most adjacent cluster head. Then, a JOIN message is sent to CH. After receiving JOIN message from all nodes, the CH then forms a communication schedule and sends this information to the node members. Like this, the organisation of clusters is performed.
Steady state phase
In this phase, the transmission of information takes place. The network communicates intra and inter-cluster using multi-hop pathways. A modified gravitational search procedure is picked by the submitted MGA for the relay nodes for information transfer.
GSA or Gravitational Search Approach is an algorithm based on population where every factor undergoes three steps. Adjustment is the first step where the influence and the efficiency of the factor is adjusted. Cooperation, the second step involves the identification of the cooperation among factors. The Third one is competition where the factors are involved in a competition to

prolong lifetime. In this work, the optimum route is found depending on CH proximity, minimum delay and residual energy by the GSA.

Gravitational algorithm

GSA is designed to draw on the motion law and the gravitational law, a stochastic optimization technique. As per 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" expressed in an equation below (3):

$$F = G\frac{M1\,.M2}{R^2} \tag{3}$$

Here G represents the gravitational constant and R represents Euclidian distance between M1 and M2.

The law of motion is expressed as an equation given below (4):

$$a = \frac{F}{M} \tag{4}$$

Where the object's mass is represented as M, acceleration as a, and force as F.

Acceleration is going to be less for great masses and the converse. Merging these laws, GSA assumes every object in the form of an agent has velocity, mass, opposition and acceleration. With the help of gravitational force of attraction, agents attract each other and the lighter ones accelerate faster in the direction of heavier agents. In the end, all of them are attracted to the biggest one. Mass is a metric of performance of an agent. Agents with greater mass are favoured.

A fundamental GSA algorithm operates in the steps mentioned below

- Population initialization

The starting positions of agents at time t is indicated in the following equation (5)

$$X_i(t) = (x_1, x_2, \dots \dots \dots . x_n\ ) \tag{5}$$

- Fitness evaluation

The fitness function is deduced at every agent location. The optimum fitness value is always the smallest fitness value and a poor one is the greatest one for a minimization problem.

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

- Update & calculations

The agents force, velocity and mass are updated depending on the deduced fitness values.

Modified GSA algorithm

In this study, a selection of the ideal relay nodes from sensor nodes is made using the provided multi-objective fitness function. The maximisation fitness function depending on factors like delay, CH proximity, and node energies is presented by the MGA. Every node meets the requirement by giving maximum value to fitness function. The equation given below represents the fitness function (6).

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

Here, $Dist_{n-CH}$ denotes the proximity of node n to the corresponding CH, $E_{res}(n)$ represents the residual energy of the node n and $D(n)$ represents the total normalized delay of sensor node n. The primary goals of fitness function below:

Delay: This delay in WSN is the addition of all delays in each node. For the node to be selected for efficient relay, the delay is supposed to be the least. Based on the below metrics, the delay of the node varies

- ETC or the expected transmission count of node
- propagation delay of the node
- Transmission delay of the network.

Delay of nodes in a WSN is given below in equation (7)

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

Here, ETC_n represents the expected transmission count of node n, TD is the total transmission of the entire network and PD_n is the propagation delay at node n.

Distance to CHs: The fitness function's second primary goal is the proximity of nodes to cluster heads. To facilitate optimum communication, this should be minimal. The distance to CHs is expressed in the equation (8) below

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

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

Energy: For the selection of cluster head, the energy of the node should be high. It is represented in equation (2).

For routing the main objectives, the efficient relay nodes are chosen.

Result and discussion

Experimental setup

A simulation is performed by differentiating between two schemes to evaluate the presented technique's outcomes. In this work, an object-oriented, discrete network simulator driven by events is used. On every wireless network, the support of routing, UDP along with multicast protocol simulation is given. A model of network is utilised where the fixed nodes are of the same type having identical capabilities, power resources, radio-transmitter devices, evenly distributed placement and energy. The base station is in a designated location at a distance from the node. The simulation tests are performed depending on the plane coordinates and static nodes. The energy of nodes are considered to be limited and thus the exchange of information is confined to the use of initial energy of nodes. The simulation metrics are taken into account in the following table (Table 1):

PARAMETER	VALUE
Application traffic	CBR
Transmission rate	1024 bytes/ 1ms
Radio range	250m
Packet length	1024 bytes
Routing Protocol	AODV
Simulation time	100s
Number of nodes	50
Area	1000 x1000
Routing methods	MFFA-ORS, FEARM [29], ELEACH [30]
Transmission Protocol	UDP
Initial Energy	100j

Table1: Simulation table

Result and analysis

This section entails the outcomes of the simulation in many situations are made light of. An attack model is executed in a 50-node network and an area of 1000 x 1000m.

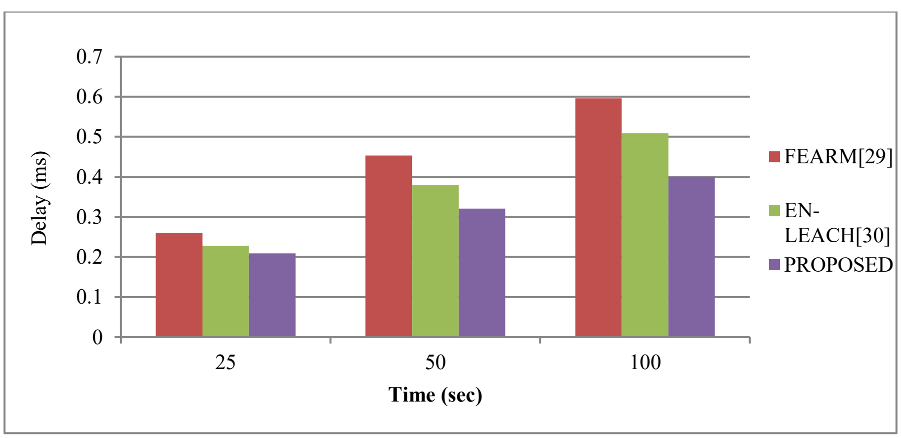

Fig.1: Performance on Delay

The efficiency of the network is contingent upon the end-to-end delay. The general network performance is impacted by more delay. In Figure 1, Performance on Delay is exhibited. Depending on the multi-objective metrics, the MFFA chooses the forwarder nodes and distance between nodes is taken into consideration to minimise end-to-end delay in the process of information exchange. According to the outcomes of the simulation, in comparison to existing protocols used in the past, the delay is lesser.

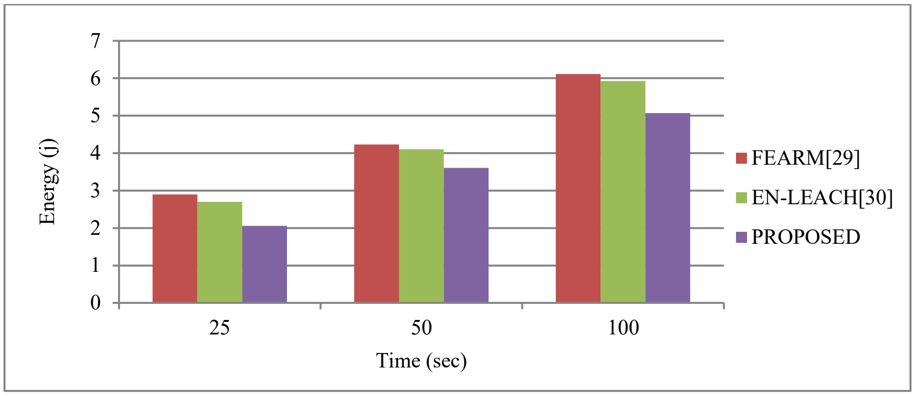

Fig.2: Energy consumption

For participation of sensor nodes in network activities, energy is a significant metric to consider. For maximum possible lifetime of a network, energy usage should be minimal. In the process of information transmission, a majority of the energy usage occurs. Optimum forwarder node selection by the MFFA, reduces the energy usage. Outcomes of energy usage are illustrated in Figure 2 proving that the presented algorithm, in comparison to other protocols, is energy-efficient.

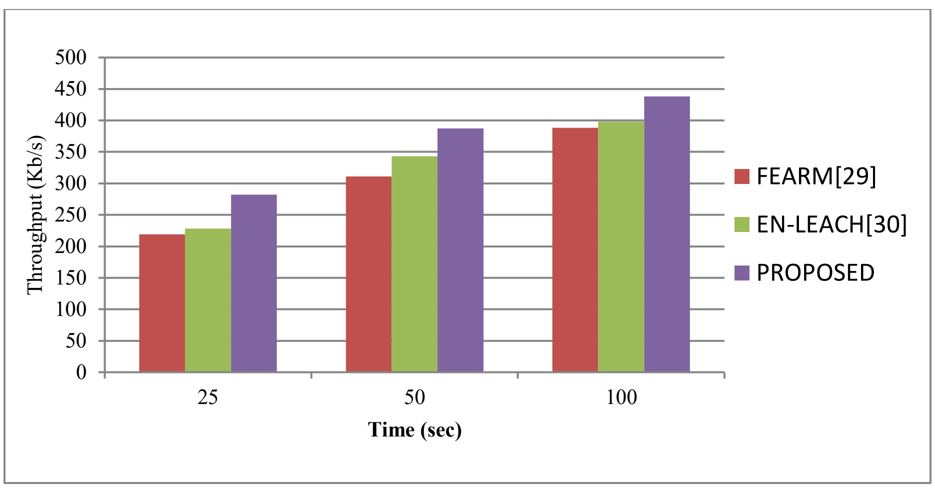

Fig.3: Throughput

Throughput is the rate at which information is exchanged successfully. Information transmission is driven by many aspects and with the help of forwarder node selection technique, these can be countered. Depending on multi-objective criteria, the MFF-ORS algorithm chooses forwarder nodes, aiding in mitigating delay in data transmission. Outcomes of throughput in MFF-ORS algorithm are shown in Figure 3, demonstrating that it is superior in information exchange in comparison to other protocols.

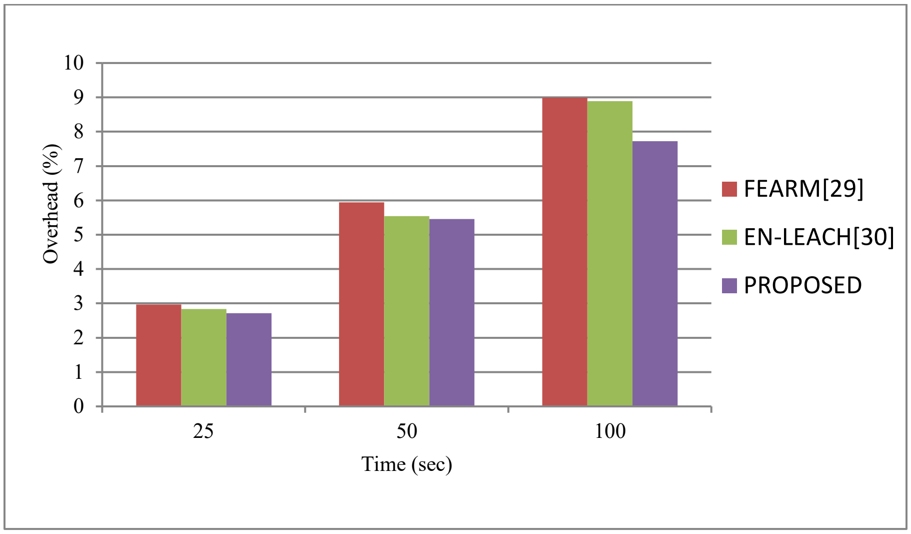

Fig.4: Routing overhead

While the algorithms operate, the magnitude of complexity encountered in the network is defined as overhead. The lesser the overhead, the more positive are the outcomes of the network. It is proven that the routing complexity is decreased upon the use of MFF-ORS algorithm. Outcomes of overhead in comparison with other protocols are given in Figure 4. The SINK node proximity metric influences the selection of CH thereby aiding in countering overhead.

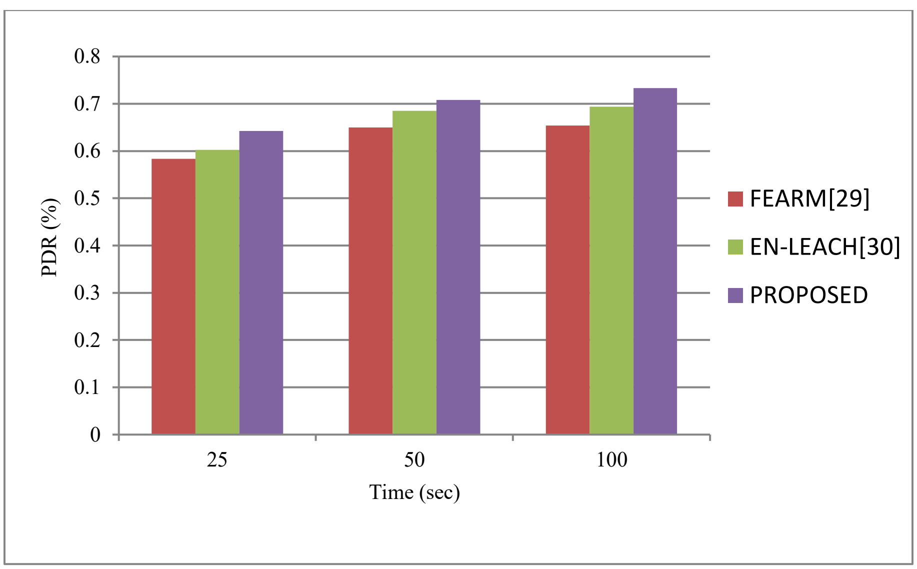

Fig.5: Packet delivery ratio

The fraction of complete information transmissions with respect to time is defined as PDR. It is often impacted by wrong forwarder node selection as delays and packet drops are more prevalent.

The MFF-ORS is efficient in mitigating this issue. The simulation outcomes of Packet Delivery Ratio is given in Figure 5 proving that the proposed technique has higher PDR in comparison to other protocols.

Conclusion

In this paper, providing energy-aware CH selection and optimal relay node selection algorithm using multi objective CH selection and modified gravitational search method for selecting of the optimal routes is proposed. Consideration of multi-objective parameters in optimum route selection depending on distance between node and CH and sensor node delay is a key benefit of employing MFF. By taking into account multi-objective metrics like residual energy, SINK proximity and probability value, optimum CH selection is performed. This presented method accomplishes great amount of energy efficiency and less overhead to the network as demonstrated in simulation results. In addition, the data delivery rate and throughput are optimised after selection of CHs based on inter-node distances and SINK as illustrated in the outcomes. The outcomes of the simulation demonstrate that the presented MFF-ORS is superior in performance in comparison to other energy-efficient routing protocols.

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