Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 1, No. 1, January 2023

A CLUSTER LEVEL HIERARCHICAL ENERGY EFFICIENT ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

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Abstract

In a wireless sensor network, a significant number of sensor nodes are dispersed across an area so that the entire region can be monitored. The processing power, memory, and battery life of the sensor node are severely constrained, and the node itself is quite small. Because of the limited power provided by the batteries, the wireless sensor network needs to lessen the amount of energy it uses in order to extend the lifetime of the system. The outmoded LEACH routing protocol is still reflected for the various research fields; however, in this paper, an upgraded version of the LEACH routing protocol is presented in the form of an energy-efficient cluster head selection that allows both distance and energy to be primary considerations. A protocol that is based on clustering can adapt the use of energy by providing all of the nodes with an equal chance of becoming the cluster head. In this paper, we focus on more recent hierarchical routing protocols, all of which depend on the LEACH protocol to improve their performance and extend the lifetime of wireless sensor networks. As a result, the distance and energy parameters choose the most energy-efficient cluster head for data communication. The results of the simulation show that the selection of cluster head in the modified LEACH protocol is significantly improved in comparison to the LEACH protocol that is currently in use. The proposed algorithm is capable of overcoming the fundamental process of cluster head selection, which, in other LEACH versions, results in an unexpected failure for some cluster heads. Additionally, the algorithm provides a good performance in terms of the network's lifetime and energy consumption in comparison to earlier versions of the LEACH protocols.

Keywords: WSN, Clustering, LEACH, Energy efficiency, Distance, Cluster head based protocols.

I. Introduction

Wireless sensor networks, also known as WSNs, are comprised of a base station (BS) that utilises a radio channel in order to communicate with an extensive number of wireless sensor nodes. In a WSN, the processes of data transmission and reception account for the majority of the operations that consume power. Due to the fact that multiple nodes may sense the same overlapping area, the elimination of redundant data is an important issue in WSN. Because of this action, the total amount of power that is consumed will decrease, and the bandwidth that is used will increase.

The structure of a wireless sensor network can be used to classify routing protocols into one of three categories: location-based protocols, data-centric protocols, and hierarchical protocols [1, 2]. A location-based protocol relies on the dissemination of location information across all nodes as an essential component of data communication. The distance to the target location affects the amount of energy that is consumed during data transmission. In the process known as flooding, data are transmitted not only to the location of interest but also to the entirety of the sensor network. Because the residual energy of each node is not taken into account, many of the nodes will eventually run out of energy, which will ultimately result in a failure of the accumulative data transmission [3-5].

A selection of necessary constraints, routing protocols to improve energy efficiency [6–8], and clustering [9–12] for guaranteeing the proper network operation are some of the alternative ways that are concerned with extending the lifetime of a network. The routing protocols used in WSN can be divided into two primary categories: hierarchical and flat. Hierarchical routing is the more common type. In the flat routing protocol, all of the nodes have been deployed at the same level, and as a result, they are regarded as being relatively straightforward. In addition, the scalability is decreased even further as a result of the overhead packet control, and if the size of the network increases, then the amount of energy that is consumed also increases. The hierarchical routing [13] implemented on the network has resulted in the division of the available space into clusters. Each cluster is given a cluster head node that is responsible for the collection of data from the other cluster nodes and the transmission of that data to the base station. Because of this, the lifespan of the network is increased, and the energy consumption in sensor nodes is balanced and optimised. When compared to flat routing protocols, hierarchical routing protocols offer superior scalability and flexibility due to their tree-like structure. In today's world, the hierarchical routing protocols [14–16] are the primary focus of the majority of the researchers.

II. Literature survey

LEACH is widely regarded as the most effective protocol for reducing power consumption while simultaneously increasing the lifetime of WSNs. Therefore, versions of LEACH have been developed to take advantage of the positive aspects of LEACH while minimising its negative effects. There are several variants of the LEACH protocols, including the ones listed below:

All of the nodes are presumed to be stationary in the energy-efficient clustering algorithm for event driven known as EECED [17]. In the process of selecting CH, one of the operating condition factors to consider is residual energy. This component can maintain a balanced flow of energy usage among the various nodes in the network, which can extend the network's lifetime, but it does result in additional overhead for BS. When selecting CH for mobile nodes in LEACH-M, Mobile [18, 19], the mobility of the node is taken into account along with the residual energy. Although LEACH-M is able to reduce the amount of lost packets that are caused by the mobility model, there are still some packets that are lost during the CH selection process for the subsequent round of CH selection.

A genetic algorithm is used in the LEACH-GA [20] protocol, which is a grouping system. To the BS, every node communicates its node identifier, the data for its area, and its choice of CH based on the optimal rate of CH. The BS uses genetic calculation operations on the obtained data to find the ideal limit likelihood and communicates it so that the group can be arranged accordingly. The production of additional overhead is necessary in order to calculate the desired percentage of CHs.

Sharawi and Emary [21] implemented grey wolf optimization (GWO) as a solution to the CH selection problem in 2017. A suitable fitness function was utilised in order to guarantee coverage of the WSN, and this information is being fed into the GWO in order to locate its optimal state. The results of the proposed model are examined alongside those of the LEACH routing protocol. There are a total of four different indicators that are taken into consideration, including residual energy lifetime, network throughput, and performance. In conclusion, the newly presented model outperforms the LEACH in almost all topologies by making use of a variety of different indicators.

WOA-Clustering (WOA-C) is an energy-efficient cluster head selection algorithm that was proposed in 2018 by Jadhav and Shankar et al. [22]. This algorithm is based on the Whale Optimization Algorithm (WOA), which is the name of the original algorithm. As a consequence of this, it is useful in the process of selecting energy-aware cluster heads based on a fitness function that takes into account the residual energy of the node as well as the sum of the energies of any adjacent nodes. In the end, the algorithm that was implemented was tested for its energy efficiency, network lifetime, overall stability, and throughput. In addition, the performance of WOA-C was evaluated in comparison to the performance of other contemporary standard routing protocols in order to demonstrate its superiority over other models.

III. Proposed method

LEACH PROTOCOL

The proposed method is the same as LEACH, which has two stages: the setup and steady stages; however, a difference occurs in the setup stage in which, in the setup stage, all the regular nodes select a random number between zero and one, then if that number is less than or equal to the threshold (T (n)) as calculated according to the next equation, the node becomes a cluster head (CH); otherwise, a node will remain ordinary. The LEACH method has two stages: the setup and Equation 1 presents the value of the threshold number T(n).

$$T(n) = \begin{cases} \frac{P}{1-P\times(r \bmod \frac{1}{P})} & if\ n \in G \\ 0 & otherwise \end{cases} \quad \text{Eq (1)}$$

Where P is the desired percentage of CHs, r is the current round, and G is the list of competing nodes that have not been selected as CHs in the previous 1/P rounds. If the current number is lower than the limit T, then Node will take over as CH for the current round (n). Once a node has been selected as a CH, it is ineligible to become CH again until all of the other nodes in the group have had the opportunity to serve in that capacity at least once. This is useful information for adjusting how much energy is being used. The second phase is known as the steady state, and it consists of the non-CHs receiving the CH requests and then sending a join demand to the CH, informing them that they are members of the group that falls under that CH [23]. In the phase known as the steady-state phase, each sensor node compiles and sends data to its CH in accordance with the TDMA schedule. In order to prevent intercluster and intracluster collisions, the LEACH protocol makes use of TDMA/CDMA MAC [24].

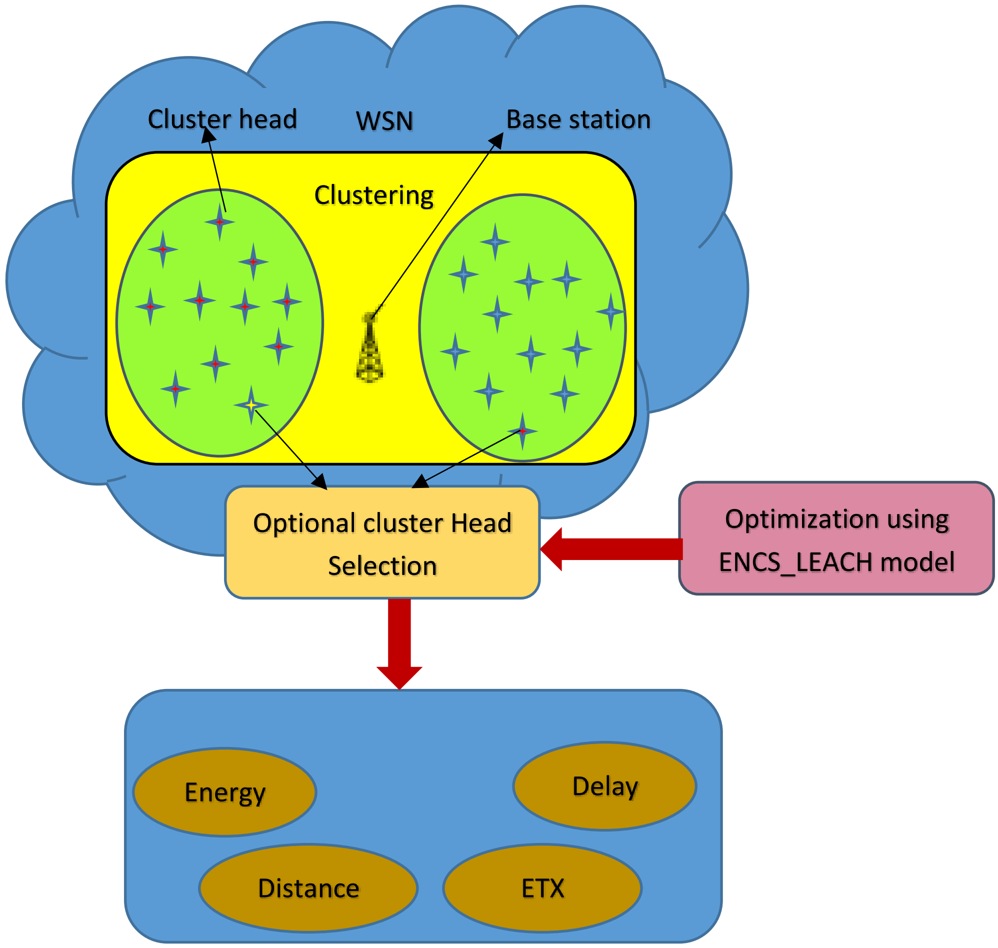

Figure 1 Proposed Cluster head selection in WSN model

PROPOSED PROTOCOL

The functioning of CEERP is divided into rounds, and each round is composed of two phases:

- Set-up phase and
- Steady state phase.

During the phase of setting up, clusters are arranged, and a multi-hop path is selected to lead from each member of a cluster to the CHs and then to the base station. During the phase known as the steady state, the data transmission takes place. The steady state phase is longer than the set-up phase so that the network's overhead can be reduced.

Set-up phase:

The set-up phase involves the following phases:

- Cluster-head selection
- Cluster formation

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

Cluster Head Selection:

At the beginning of the set-up phase, it is necessary for each node to determine its distance from the SINK node and then communicate this information as well as details regarding the residual energy to its neighbouring nodes. A probability value is computed for each node by selecting a random value between 0 and 1, and using this value in the calculation.

Calculating the distance between the node and the SINK utilising the Euclidean distance, as shown in the following equation: (2)

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

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 (3):

$$RE = E_{initial} - E_{consumed} \quad \text{Eq (3)}$$

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

When the distance to the SINK is at its shortest and the node's residual energy is greater than that of the other nodes, it is promoted to the position of CH.

Cluster formation:

After the cluster heads have been chosen, the base station will send a CH ADV message to its neighbours. This message will then be propagated outwards by the cluster heads. Each member node determines the closest cluster head based on the signal strength of the CH ADV messages it has received and uses this information to choose the nearest cluster head. If the cost of sending data directly to the base station is lower when a sensor node does not have to communicate with the cluster head, then the node will send the data directly to the base station. If that is not the case, it makes the decision to join the cluster that has the nearest cluster head. After every node has determined which cluster it is a part of, that node will send a JOIN message to the cluster head. After the cluster head has received JOIN messages from all of the nodes that are interested in joining the cluster, it will generate a communication schedule and then broadcast it to all of the member nodes. This results in the organisation of clusters.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 1, No. 1, January 2023

Notation:

N = the total number of nodes

CH stands for cluster head, and BS refers to a base station.

Setup Stage:

At this point, clusters are formed, and candidate CHs are selected.

A random number T (n) between 0 and 1 is chosen using the for each (N) function.

if (T (n) is less than the threshold value), then

N broadcasts a message announcing its status as the Cluster Head (CH), and then N becomes a CH.

Otherwise, N will become a regular node.

N is given the message that CHs End If has been announcing.

Calculate the distance from N to CH as well as the distance from CH to BS. End for Each (CH)

N will select the CH that has the shortest distance between it and CH and BS.

N provides information to the chosen Cluster-Head and joins the cluster as a member.

Cluster-Head is responsible for creating an End for Each (CH) TDMA schedule for each node in order to transfer data.

TDMA schedules are made by the Cluster-Head, and they are advertised to all of the nodes in the cluster by the Cluster-Head End for Each (CH) node. TDMA schedules are used to transfer data.

TDMA schedule is advertised to each node in the cluster by Cluster-Head

End_for

Steady state phase

During the phase known as the steady state, data transmission takes place. Communication can take place within clusters as well as between clusters using the network's multi-hop routes. In this article, we present CEERP as an optimal relay node selection algorithm that selects relay nodes for the purpose of the data transmission process.

Notation:

N stands for the number of nodes.

CH stands for cluster head.

Steady-state Stage: \sFor_ The information that has been sensed is compiled by each (N) N.

N sends the information that has been gathered to the Cluster-Head at the TDMA time point that corresponds to it.

End for

For Each (Cluster-Head) Cluster-Head collects information from the individual cluster nodes.

The data are compiled by the Cluster-Head.

The information is sent down to the base station by the Cluster-Head. End for

IV. RESULT AND SIMULATION ANALYSIS

There have been a lot of different protocols considered for use in wireless sensor networks. Within the scope of this study, we focus on analysing two different protocols, namely the LEACH protocol and the proposed method.

Regardless of how far away the CH is from the base station, a node will use the LEACH protocol to choose the CH that is located in the closest proximity to it. Using the proposed method, a node chooses a low distance that is calculated from a node to every CH to the base station. This distance is then communicated to the base station.

The hypotheses that we have developed in order to evaluate LEACH and the proposed method are summarised in Table 1, which can be found below.

The simulation is run by comparing the proposed method with two other different schemes so that the performance of the proposed method can be evaluated. This project has made use of NS2, also known as network simulator 2, which is a research-oriented network simulator that is both object-oriented and discrete event driven. Its primary focus is on networking. All wireless networks come equipped with the ability to simulate routing as well as UDP and multicast protocol support. In this investigation, a network model is utilised, in which fixed sensor nodes in a network are existed with homogenous types. These nodes have the same radio-transmitter devices, same capabilities, and constrained power resources, all while having the same initial energy, and uniform deployment. Additionally, these nodes all have the same initial deployment. The BS is stationary, and its location is some distance from the sensor node. Simulation tests are executed by basing their parameters on the coordinates of the planes and the static nodes. It is assumed that there will be limited energy nodes, and once the initial energy of a node has been depleted, there may be restrictions placed on the information that can be sent or received at that node. The simulation parameters are taken into account in the table that can be found below (Table 1).

PARAMETER	**VALUE**
Traffic protocol	CBR
Transmission rate	1024 bytes/ 1ms
Radio range	250m
Packet size	1024 bytes
Routing Protocol	AODV
Simulation time	100s
Number of nodes	50
Network Area	1000 x1000
Routing methods	CEERP, FPU-DA, LEACH
Data Transmission Protocol	UDP

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 1, No. 1, January 2023

Initial Energy of nodes	100j

Table1: Simulation table

Simulation result and analysis

In this section, we will discuss the presentation of the obtained results from running simulations on a variety of different scenarios. The attack model is implemented across a space measuring 1000 metres by 1000 metres and utilising a network with 50 nodes.

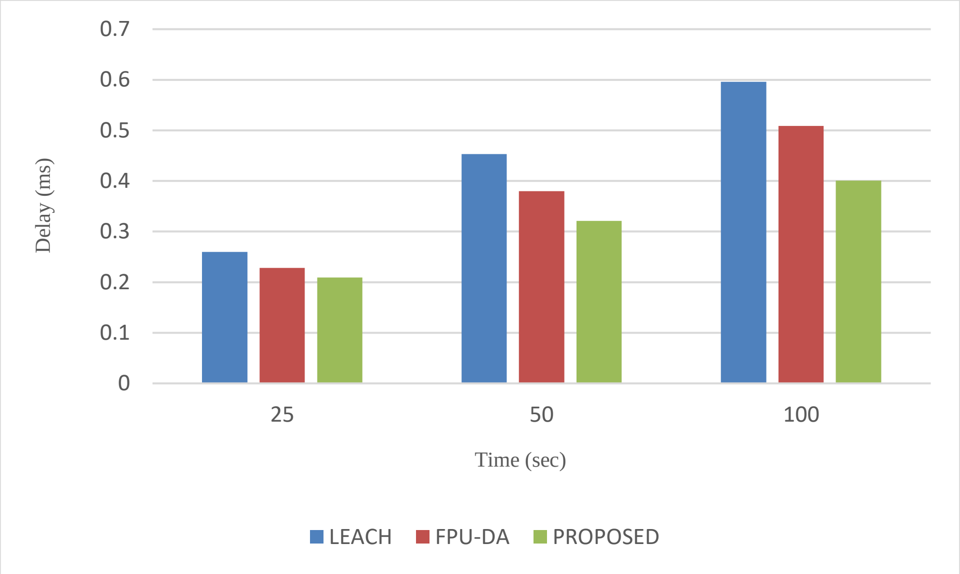

Fig2: End to End Delay

The effectiveness of the network can be determined by the end-to-end delay. The overall performance of the network is impacted when there is a higher delay. The forwarder nodes are chosen by CEERP according to a set of multi-objective parameters, the most important of which is an estimation of the distance between the nodes. This helps to cut down on the end-to-end delay that occurs during data transmission. The findings of the simulation demonstrate that the delay is significantly less than that of the protocols that were utilised in the past. Figure 2 illustrates the lag experienced by the network.

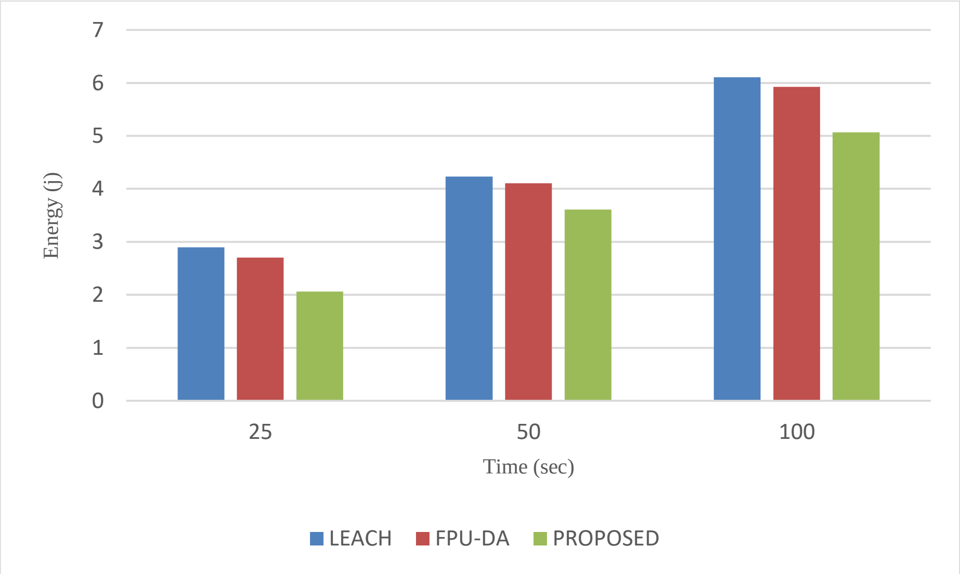

Fig3: Energy consumption

It is absolutely necessary for the sensor nodes to have access to energy in order for them to take part in the activities of the network. The minimal amount of energy consumption extends the lifetime of the network even further. Major energy consumption happens during data transmission. The CEERP forwarder node selection helps to cut down on the amount of energy that is consumed by selecting the appropriate forwarder node. The findings demonstrate that the proposed algorithm is superior to the other protocols in terms of optimising the amount of energy it consumes. The amount of energy used by the network is represented in Figure 3.

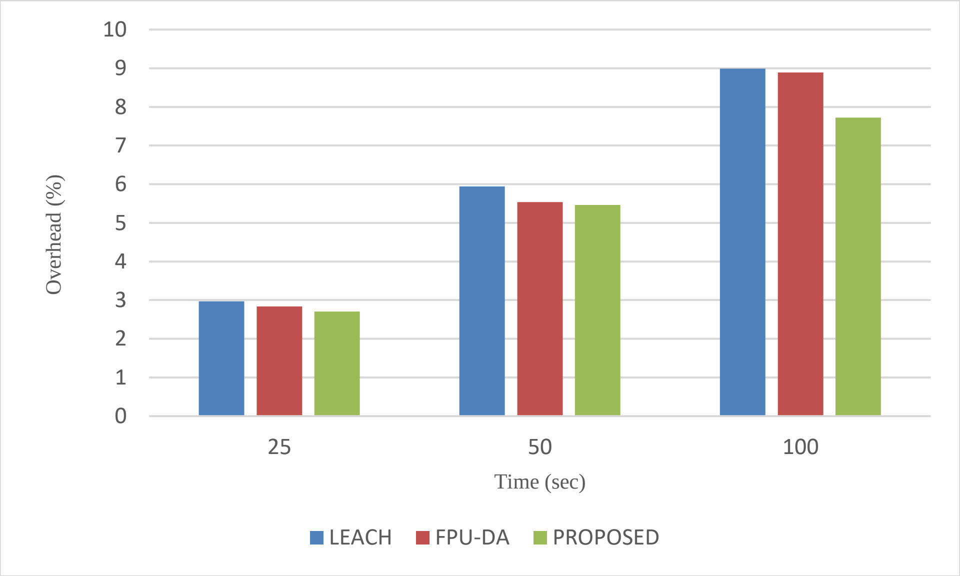

Fig4: Routing overhead

The amount of complexity that the network encountered while processing these algorithms can be defined as its overhead. The network achieves better results with less administrative burden. The complexity of the routing is simplified through the utilisation of CEERP and the data aggregation through the utilisation of CEERP selected forwarder nodes. Additionally, the selection of the CH is determined by the distance to the SINK parameter, which helps to cut down on the communication overhead that occurs between the CH and the SINK. Figure 4 illustrates the routing overhead that is incurred by the network.

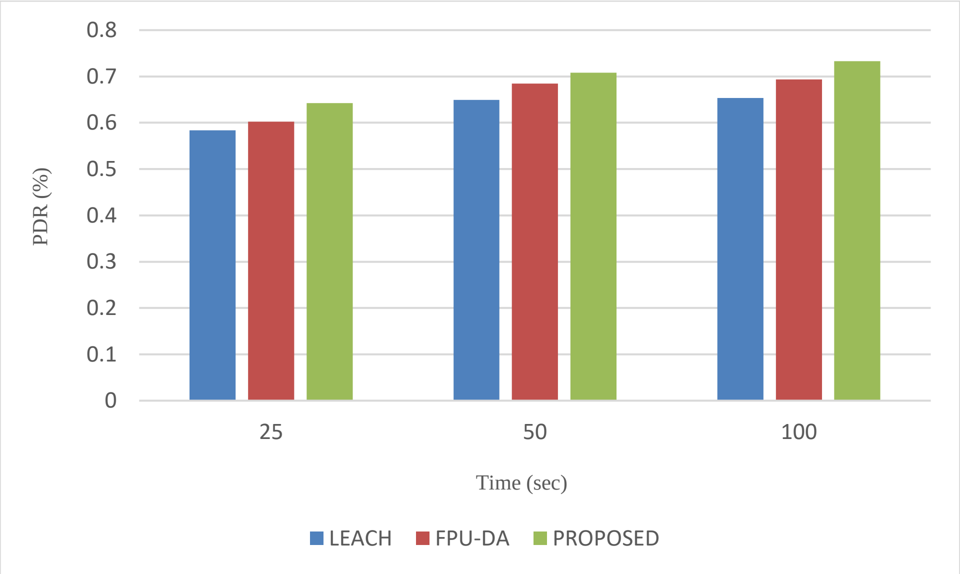

Fig5: Packet delivery ratio

The percentage of successful data deliveries (PDR) is defined as a ratio over time. The PDR is frequently impacted by improper forwarder node selection, which results in delay and packet drops. This problem is remedied by the CEERP, which chooses the forwarder nodes that have adequate capacity to carry out the data transfer. The findings from the simulation demonstrate that PDR value is greater than the algorithms that were proposed in the past. The percentage of successfully delivered packets is shown in Figure 5.

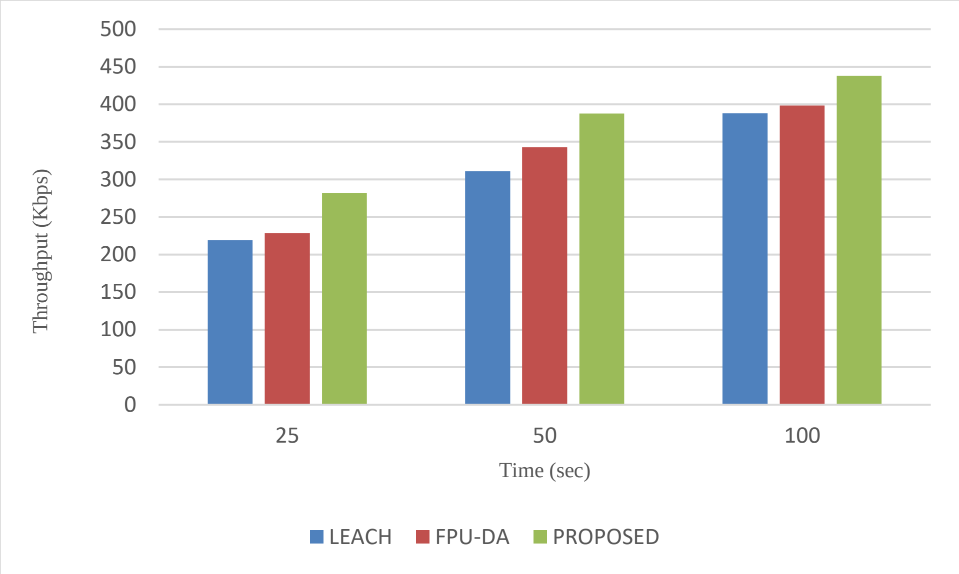

Fig6: Network performance

The successful data delivery rate is referred to as the throughput. The transmission of data is frequently impacted by a variety of factors, most of which can be circumvented with an effective forwarder node selection process. The CEERP algorithm chooses forwarder nodes on the basis of multiple criteria, which ultimately results in a decreased amount of delay in the delivery of the data. The graphs demonstrate that the proposed CEERP algorithm successfully delivers data, as compared to the protocols that were used previously. The throughput of the network is displayed in Figure 6.

Conclusion:

In this paper, a proposal is made to provide an enhanced LEACH selection as well as energy aware routing in order to choose the most appropriate CH selection. An investigation into the power consumption of the suggested proposed approach strategy in comparison with LEACH was carried out through the use of a simulation-based performance study. The findings indicate that there is a significant reduction in the amount of power that is used, which will result in an increase in the lifetime of a network. Additionally, the findings demonstrate that the data delivery rate and throughput have significantly increased for inter-cluster data aggregation as a direct result of the selection of CHs based on the distance between nodes and the SINK approach. Last but not least, the performance of the suggested method is superior to that of LEACH.

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