

# A Modified Power-Efficient Gathering in Sensor Information System (MOD-PEGASIS) for Routing in Wireless Sensor Network

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**Abstract**— Wireless Networking (WSN) uses numerous sensor nodes with multiple processing, sensing capabilities in order to monitor/ track a particular area which is far from a human approach. Because sensor nodes are mainly battery-powered and are extremely limited in terms of energy sources, it is necessary to explore energy optimization methods to extend the life of the WSN. In this research work, we mainly focused on to minimize the unnecessary wastage of energy and hence enhance the network performance. A Modified power-efficient gathering in sensor information systems (Mod-PEGASIS) algorithm is designed to select an appropriate Cluster Head (CH) by hybridizing the Cuckoo Search (CS) and Firefly algorithm. Initially, the sensor nodes are deployed in the defined network area on random basis. Then, the entire network is divided into different clusters each includes an individual CH. After the formation of optimal route, the selection of route is done using artificial neural network (ANN) approach. The simulation results illustrated that the designed approach can effectively improve the network performance in terms of end-to-end delay, packet drop ratio and energy consumption rate. The energy up to 4.52 % is obtained compared to the existing work.

**Index Terms**— Wireless Sensor Network, Power-efficient gathering in sensor information systems, Cuckoo search, Firefly, Artificial Neural Network.

## 1 INTRODUCTION

WSN is a kind of wireless communication network that consists of a large number of tiny elements known as nodes [1]. Due to their low deployment cost, these networks find application in distinct fields such as monitoring weather and environmental conditions, healthcare system and many more. WSN mainly consists of two sides such as; a Base Station (BS) and a number of sensor nodes that are communicating with each other by sensing physical parameters from the outside environment [2]. BS is used to collect data from these sensor elements and then take decision so that the data can reach the desired end-user. Each sensor nodes have performed different operations such as collection of data, data processing and then communication [3]. Fig 1, represents the block diagram of sensor node. The sensors are the tiny elements that are used to examine the physical quality like temperature, humidity and motion. The storage unit is utilized to memorize the collected sensor data [4]. The collected data is passed to the controller unit for further processing. The controller has taken decision like when and where the data is routed as well as responsible for data aggregation. The sensor nodes are powered by the batteries as the nodes are deployed in remote area [5]. The transceiver block is used for the reception as well as transmission of the data so that the nodes can communicate successfully within the network [6].

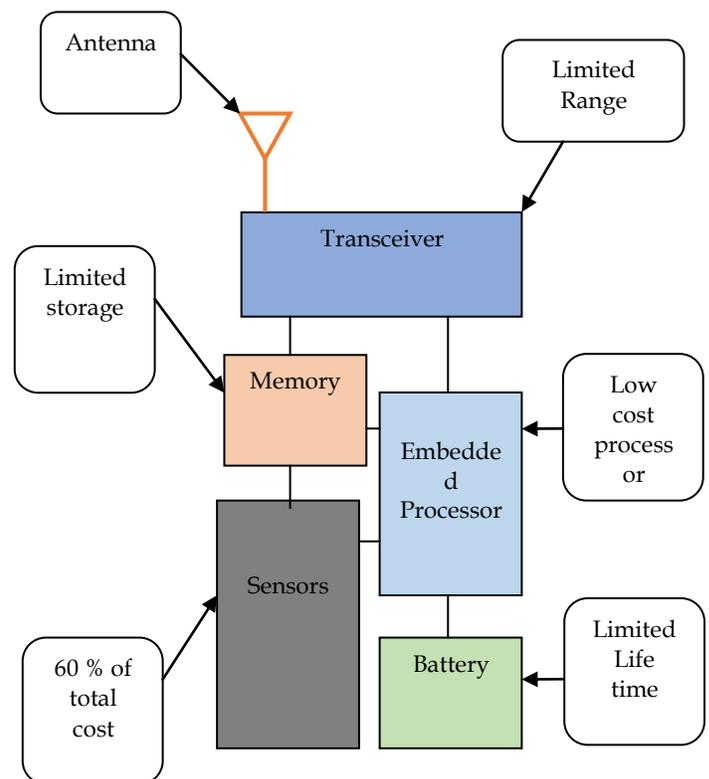


Fig. 1. Block Diagram of a sensor node in WSN [7]

The working operation or the life of these nodes depends upon the battery attached to these nodes. Also, the nodes are deployed in the area which is far from the human approach [8]. Therefore, it is tough to replace or recharge node's battery, which affects the overall performance or the lifetime of the

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network. To preserve node's energy, become an essential task in the communication of WSN. Due to battery exhaustion, failure of communication link as well as node's may arise; therefore, an alternative route must be suggested immediately to the network to continue communication between the source and the end-user [9]. But the direct transmission between the source node and the destination node consume more energy compared to the transmission of data through multiple stages of shortest distance. At this point, the concept of clustering helps a lot, in which, the nodes have to communicate with the CH [10] instead of all neighboring nodes. Therefore, CH performs multiple tasks such as data aggregation, data compression and the transmission of data to the BS as well as to their nearby CH [11]. Every time, the nodes whether they are inactive mode or in idle mode consumes energy and hence to save energy-efficient routing protocol is used [12]. In this paper we have used PEGASIS as a routing protocol, which has been designed mainly to save energy so that the lifetime of the network can be increased. This protocol mainly has two targets one is to increase the lifetime of the sensor nodes by using collaborative scheme. The second one is to minimize bandwidth consumption by assigning the data to its nearby node.

### 1.1 Paper Contribution

The main focus of this paper is to design an energy-efficient routing protocol by adopting techniques such as clustering, swarm intelligence algorithms along with artificial intelligence technique. The designed protocol will provide the following contribution in the WSN:

1. PEGASSIS routing protocol is implemented to find best intermediate nodes in existing route for data transmission from the transmitter to the receiver node via CH.
2. To improve and create a secure route, a combination of CS with Firefly is used as an optimization technique for the better selection of CH.
3. ANN is used as a classifier mechanism with optimized PEGASIS routing to minimize the energy consumption rate for data transmission in WSN.
4. QoS parameters are calculated and compare with PEGASIS routing protocol to validate the designed routing mechanism.

The rest of the article is arranged as follows. Section 2 describes the related work on WSN. Section 3, demonstrates the proposed network and approaches. Section 4, describes the results and discussion obtained after the experiment performed in MATLAB simulator. Section 5, concludes the overall research followed by its future opportunities.

## 2 RELATED WORK

A number of documents/ research papers related to energy optimization in WSN have been published. The

results/finding of those papers has been discussed in this section. The researchers Jie et al [13] in the year 2009 have proposed MAC-based protocol, which was later investigated to design an energy-efficient routing scenario. In his research, the authors have mainly focused to solve the issue of coverage area. Here, coverage area is defined as the requirement of nodes that are used to cover the given/desired area. The authors have designed a "k-coverage" algorithm along with a novel objective function to reduce node's total energy consumption as well as enhance the reliability of the nodes. According to their problem definition, the energy consumption rate can be stated as;

$$K*N*((r*r)/A)=.3849K$$

Where K, N, r and A, are known as the factor of energy consumption, the number of nodes, radius of coverage and area of the desired network respectively.

Many researchers have focused on energy conservation routing protocols in recent years. Nearly LEACH is the most popular hierarchical protocols that have been proposed twenty years ago [14]. There are mainly two kind's nodes that a LEACH protocol includes such as CH and ordinary nodes. The ordinary nodes collect data from the desired area and transfer the data packet to its nearest CH. The CH receives the data and then send the data to the receiving node. The concept of CH has been used to avoid long-distance communication between the sink node and ordinary node and hence save much energy. The selection of CH is performed on random basis, which results to degrade the performance of the network. Also, as the CH's are directly communicating with the sink node which causes large amount of energy dissipation.

The above-mentioned problems are removed using PEGASIS as a routing protocol for WSN. In PEGASIS, the sensor node forward data to its nearby node that is nearest to the sink node. In this algorithm, the data is transmitted in the form of chain and it is the duty of the head node to transfer data to the sink node. In this every node behaves like a leader node and hence balance the energy consumption. As this protocol used the concept of multi-hop communication and hence save energy by avoiding the long distance between the transmitting and receiving node. But, the delay using PEGASIS is high due to the use of multi-hop propagation [15].

In [16] the concept of clustering has been used to design an energy-efficient routing protocol. The receiving node moves along with the CH and gathers information via single-hop communication process. In this research work, the shortest distance has been determined on the basis of spanning graph scheduling algorithm, which results in increased lifetime and reduces the network complexity. In [17] tree clustering technique has been used for the collection of data. The algorithm has worked into three stages such as the creation of tree, decomposition of tree & selection of sub rendezvous point and data collection phase. Using the mentioned process, receiving node moves towards the centralized point and sub rendezvous point gather information from that node. In [18] an evolutionary multipath energy-efficient routing protocol

(EEMER) has been presented. The network of a maximum of 200 nodes has been used during the experimental work. Also, to show the effectiveness of the proposed work comparison between traditional routing algorithms such as LEACH, PEGASIS and TEEN algorithms against EEMER algorithm in terms of end-to-end delay, energy consumption, and packet delivery ratio has been provided. The researchers have combined the PEGASIS routing algorithm with the evolutionary-based optimized scheme named as cuckoo search for the appropriate selection of CH during the process of clustering.

### 3 PROPOSED WORK

In this research work, we have designed a simulation model for WSN using the concept of PEGASIS routing mechanism with hybridization of Cuckoo Search and Firefly optimization algorithm based on ANN as a classifier

. The concept of PEGASIS routing mechanism is applicable for each communicating node to receive and transmit the data packets to closest neighbor nodes via cluster head which is as known as leader node. This routing approach works on the basis of energy load distribution mechanism in the network. The procedural steps of simulation are given in the form of block diagrams.

#### 3.1 Network Creation

Firstly, we place the same number of nodes using the randomly generated x and y coordinates in the simulation area which is considered as 1000m<sup>2</sup> and after that, a node is selected as transmitter node and other as receiver node based on random selection process.

#### 3.2 Energy Model

During the simulation of the work, the energy model, which was presented by Jia et al. (13, 2009) has been considered. Following assumptions are considered;

1. Sensing radius of the node
2. Power loss in free space
3. Power loss in the channel

Therefore, the energy consumption of a single sensor node (k) can be determined as:

$$Energy_k = \begin{cases} M_{outs} \times r_k^1 \\ M_{mpf} \times r_k^4 \end{cases}$$

Where  $Energy_k$  represents the energy consumption of  $k^{th}$  node,  $M_{outs}$  and  $M_{mpf}$  are represents the model of energy consumption in free space and multipath fading respectively.  $r_k$  is the sensing radius of  $k^{th}$  node. Therefore, the total energy calculated for the given network is defined as:

$$E = \sum_{k=1}^n Energy_k$$

The energy consumption calculated per area is given as;

$$Energy_{area} = \frac{Energy}{S_A}$$

$S_A$  Represents the sensing area. The entire network is divided into 2x3 grids, and hence  $S_A = K^2/6$ .

The distance between the n numbers of sensor nodes is calculated by

$$D(x, y) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

Here, x y are the points within the sensing radius of  $k^{th}$  node

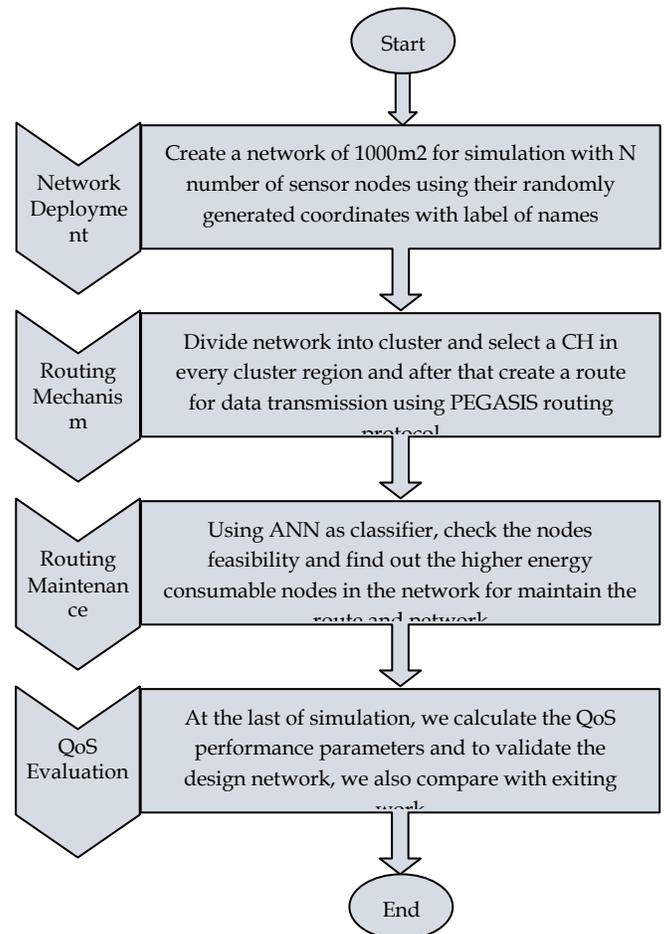


Fig. 2. Proposed Work

#### 3.3 CH selection

In this scenario, the hybridization of cuckoo search and firefly algorithm is used to select a cluster head for data transmission and a cluster head is assigned to each cluster region. We already know that PEGASIS routing mechanism faced several issues during selection of a cluster head. So the hybrid approach distributed the energy load equally among all nodes in the network and then find out the reliable node using the fitness function which is considered as cluster head or leader node.

### 3.4 Route Formation

The designed wireless network, which consists of the number of nodes, is shown in Fig. 3. The network is divided into six number of clusters named as C1, C2, C3, C4, C5 and C6 respectively. With the help of hybridization of CS and Firefly algorithm for PEGASIS routing mechanism, we defined a CH in each cluster region, which acts as a leader node. In each cluster, the CH is represented by a different colour of circle whereas nodes are represented by simple circle. After that a route is created between transmitter nodes to receiver node using the concept of optimization. The working of PEGASIS routing algorithm is written as follows;

The main concept behind PEGASIS is to receive information from the transmitter node and send to its nearest node and behave like a leader node throughout the communication process. This process helps to distribute load evenly. The nodes are placed on a random basis and are arranged in such a manner so that a chain can be formed. On the other hand, it is the duty of the BS to execute this chain and then broadcast it to the entire network. The network has been simulated for 50 numbers of nodes in which a BS has been positioned at remote place from the nodes.

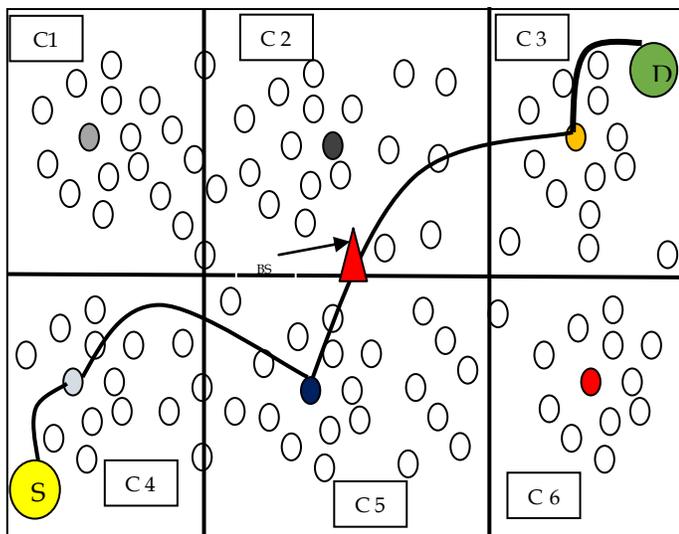


Fig. 3. Route Formation Using Mod-PEGASIS

For the formation of the chain, it is assumed that the entire nodes have global knowledge of the network a hence followed the greedy chain algorithm. The construction process of chain is started with the farthest node from the BS.

The working of PEGASIS routing is based on the distribution of energy to each node in a balanced way. So, this routing protocol always considered the farthest neighbour node in route for data transmission because energy consumption of each node is same. The source node transmits data to its nearest CH, and the CH send data to the farthest CH which is nearest to the BS as shown in Fig. 3. After that BS send data to the CH which is nearest to the receiving node and farthest from the BS. After that the data transmission starts and the route maintenance process is described in the following section. The working algorithm of Mod-PEGASIS is written as follows

#### Algorithm: Mod- PEGASIS using CSA and FFA

Requirements: Nodes (N), Properties of Nodes (P), Coverage Area (CA), Coverage Limit (CL), Transmitter node (TX), Receiver node (RX), Cluster Head (CH) and Base Station (BS)

Output: R-TX to RX: Route from transmitter node (TX) to receiver node (RX) via Cluster Head (CH) and Base Station (BS)

For each N do with respect to i

Node-Energy = N (i)

Balance the node energy using PEGASIS protocol

If N (i) == Balanced

Node-Energy = not required balancing of energy

Else

Node-Energy = required balancing of energy

End

End

Based on the Node-Energy, divide to network into sub region which is known as cluster and create a cluster head in each cluster and to select cluster head, hybridization of CSA and FFA is used

Call CSA with their operating functions

- Egg Size (ES-All Node-Energy)

- Current Egg (CE-Particular Node-Energy)

- Respective Eggs (RE-Neighbor Node-Energy)

Set fitness criteria of CSA for cluster head selection

Fitness\_function,  $f(f) = \text{True};$  if  $RE > CE$

False; otherwise

Calculate size of Node-Energy such as (R-row, C-column)

For each R do with respect to i

For each C do with respect to j

$F_s = CE(i, j)$

$F_t = RE(i, j)$

$f(f) = \text{Call Fitness\_function}(F_s, F_t)$

Fitdata=CSA (f (f), ES)

End

End

If Fitdata == True

Consider as CH

Else

Consider as Normal communicating node

End

To validate the selected CH by CSA, FFA is used

Call FFA with parameter - Iterations (ITR)

- Population of Firefly (S)

- Fitness function f (fit)

- Selected CH (SCH)

Calculate, T = Number of Selected CHs

Fitness function:

Fitness\_function,  $f(\text{fit}) = \text{True};$  if selected CH is better

False; otherwise

For each T and ITR do with respect to i

$F_s = \text{Node-Energy SCH}(i)$

$F_t = \text{Node-Energy of S}(i) / N$

$f(\text{fit}) = \text{Call Fitness\_function}(F_s, F_t)$

FitCH=FFA (f (fit), ES)

```

End
If CH == FitCH
    Selected CH by CSA is true
Else
    Selected CH by CSA is true
End
Create an empty Route, R= []
R (1) = TX
Search nearest CH with respect to the TX
R (2) = Nearest CH
.
.
R (mid) = BS
.
.
R (Last) = RX
Returns: R as a route from transmitter node (TX) to receiver
node (RX) via Cluster Head (CH) and Base Station (BS)
End
    
```

### 3.5 Route Maintenance

After that, data transmission is starting using the selected route by hybrid approach and if any communication problem occurs then the concept of ANN is utilizes to detect the irrelevant nodes in the node which is the cause of energy consumption.

#### Algorithm: ANN

**Input:** Nodes features as a Training Data (T), Target (G) and Neurons (N)

**Output:** Selection of best route

```

Initialize ANN with distinct constraints
- Epochs (E)
- Performance parameters: MSE, Gradient, Mutation and Validation Points
    
```

For each set of T

**Group = Categories of Training data**

**End**

**Initialized the ANN using T & G**

Net = Newff (T, G, N)

Set the training constraints as per desire and train the network

Net = Train (Net, T, G)

Classify = fail node within route using trained Net

**If** Classify = True

Optimized route = Node consider in route

**Else**

Node not consider in route

**End**

**Return;** Optimized Route with best intermediate nodes

**End**

## 4 RESULTS AND DISCUSSION

The proposed Mod-PEGASIS routing protocol is implemented in MATLAB simulator by using the concept of optimization and artificial intelligence. The modifications in PEGASIS routing mechanism have been executed with WSN. The simulation parameters that have been assumed during the execution are shown in table 1.

TABLE 1  
SIMULATION PARAMETERS

Number of Nodes	100, 120, 140, 160, 180, 200
Channel Type	Wireless
Traffic Type	TCP
Antenna Type	Omni-directional
MAC Type	IEEE 802.15.4
Routing Protocol	Mod-PEGASIS
Number of packets	50
Simulation Area	1000×1000 square meter

The result of the designed routing algorithm has been calculated in terms of packet drop rate, delay and residual energy of the nodes. The performance of the presented energy-efficient algorithm is compared with PEGASIS and ModPEGASIS algorithm as shown in table 2.

TABLE 2  
END- TO END DELAY (MS)

Number of Nodes	PEGASIS	Mod-PEGASIS	EEMER
100	6.8	4.8	5.0
120	7.2	5.6	6.0
140	8.7	6.7	7.0
160	10.5	6.9	7.1
180	14.6	7.8	8.2
200	18.7	8.2	8.5

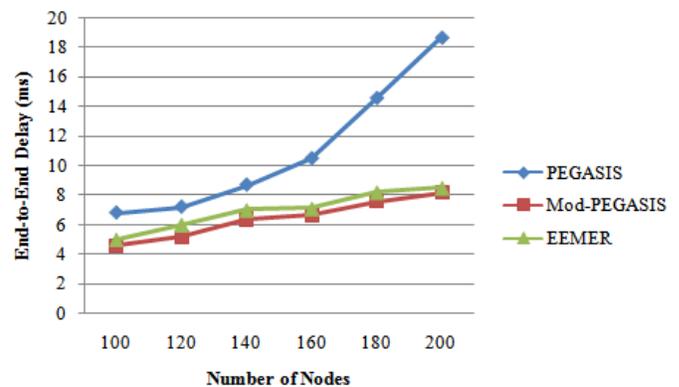


Fig. 4. Delay analysis of the proposed model

Fig. 4. represents the performance of the proposed Mod-PEGASIS approach against PEGASIS and existing EEMER []

technique. From the Fig, it is clearly seen that the end to end delay has been increased with the increase in the number of nodes. The reduction in the delay of about 52.2 % has been examined when the number of nodes is at 200 and about 29.41 % while considering 100 numbers of nodes.

TABLE 3  
PACKET DROP RATIO (PDR)

Number of Nodes	PEGASIS	Mod-PEGASIS	EEMER
100	0.56	0.16	0.2
120	0.75	0.21	0.25
140	0.82	0.22	0.26
160	0.89	0.23	0.27
180	0.91	0.25	0.29
200	0.95	0.27	0.30

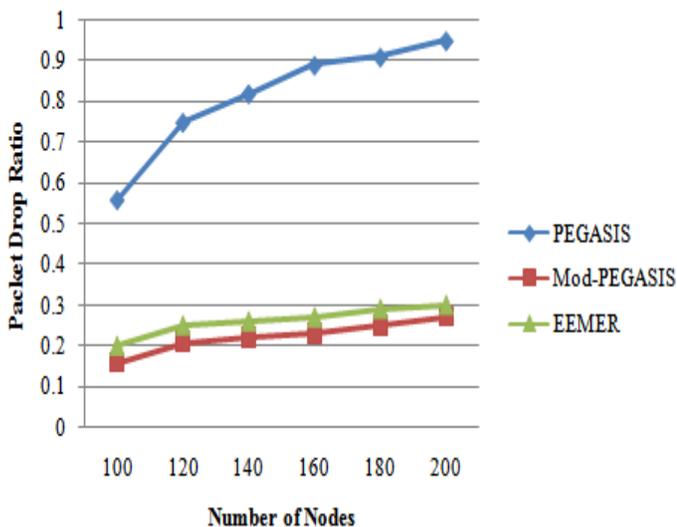


Fig. 5. PDR

The next QoS parameter that has been considered in justifying the performance of the designed Mod-PEGASIS protocol is the PDR that has been shown in the form of a graph as depicted in Fig 5. It has been observed that the traditional cluster-based technique (PEGASIS) make sure a maximum transmission of data packet while integrating with optimized and artificial intelligence techniques. From the graph an enhancement of about 65.43% from the traditional PEGASIS approach and about 15.38 % compared to the existing EEMER approach.

TABLE 4  
ENERGY CONSUMPTION (J)

Number of Nodes	PEGASIS	Mod-PEGASIS	EEMER
100	70	55	60
120	195	160	180
140	240	195	220

160	355	330	340
180	385	370	380
200	487	475	480

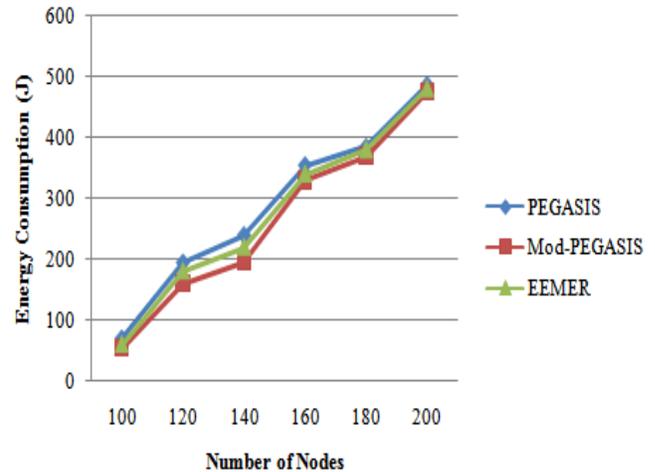


Fig. 6. Energy Consumption

The measured energy consumption with a different number of nodes has been presented in Fig 6. From the above graph it has been clearly observed that with the increase in the number of nodes the energy consumption has also been increased. The percentage reduction in the energy consumption of the proposed Mod-PEGASIS approach compared to the simple PEGASIS routing algorithm is about 8.49 % and about 4.52 % compared to existing EEMER techniques.

## 5 CONCLUSION

In this research article, an energy-efficient Mod-PEGASIS algorithm for WSN based on hybridization of CS and Firefly algorithm using ANN has been designed. Using PEGASIS routing we achieve a balance between energy utilization by each node. This is obtained by adjusting the sensing radius of every node. Initially, the nodes along with BS are deployed randomly in the defined network area and then the network is divided into different grids. The energy consumption of each grid has been measured. Then, the CS with Firefly algorithm is used to adjust the radius of sensing node as well as to select appropriate CH. Finally, we adopt ANN classification approach to select the efficient route between transmitter and receiver end. Simulation results show that the designed Mod-PEGASIS approach perform better compared to simple PEGASIS and existing EEMER approach.

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