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Hybrid energy efficient network using firefly algorithm, PR-PEGASIS and ADC-ANN in WSN

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ABSTRACT

Every wireless sensor network is threatened mainly due to Lifespan, Energy, Distortion, Security etc. Life time and energy are two major concerns of Wireless Sensor Network. The way Energy is utilized in the network will define how much the lifespan of a WSN is. To improve the lifespan of sensor nodes, the researches focus on the reduction of energy consumption rate of the nodes during the process of transmission and reception of data. The foremost emphasis of this research work is to project a distortion free wireless network with the help of appropriate Cluster head selecting through firefly algorithm. A grid-based clustering approach is used to select an appropriate CH from clusters of networks. The aim of selecting an appropriate CH is to reduce the energy consumption rate followed by swarm inspired optimization algorithm such as Firefly algorithm. After the selection of the CH, the route is form by using Proficient Routing based Power-Efficient Gathering in Sensor Information (PR-PEGASIS) hierarchical routing protocol. To face the distortion in the network due to battery discharge problem or from various other issue, Active Distortion Control Artificial Neural Network (ADC-ANN) is used to classify the optimal nodes within the route. At last, the comparison between existing work and proposed work is performed to determine the accuracy of the proposed work. This research emphases the best possible utilization of existing techniques and framed new algorithm to reduce the energy consumption of the WSN. The energy consumption rate up to 17.6% is reduced as compared to the existing work.

1. Introduction

WSN is an interconnection of sensor nodes connected with each other in a network through a wireless medium. WSN finds application to monitor the physical and the environmental condition of the remote places [1]. WSN suffers from fewer energy resources, limited computing capacity and the wireless communication might be broken most of the time that creates network failure problem [2]. Therefore, it is the requirement of a wireless network, that the Sensor nodes must contain a battery with finite power but, in practice, it is not possible. Thus, the main concern of this paper is to reduce the energy consumed by the sensor node [3].

Fig. 1 represent the structure of WSN, which comprises of n number of nodes. The sensor nodes help to collect information from a remote area and for further processing pass the information to the computer system through gateway node [4].

As the data is communicated through one node to another node within the network, therefore, each sensor node absorbs energy during reception and transmission of the data in WSN, the energy spent by sensor nodes is segregated into two major types: 1. Useful Energy Consumption 2. Wasteful Energy Consumption [5]. Useful energy consumption comprises of the energy consumed by various factors such as sending and receiving data, processing and forwarding query request. Wasteful energy consumption comprises of energy consumed by sensor nodes during ideal state and retransmission of data during packet collision. Therefore, we can say that a small part of the energy is utilized during transmitting and receiving the data and most of the energy is wasted [6]. To reduce the energy consumption rate in WSN, we need to

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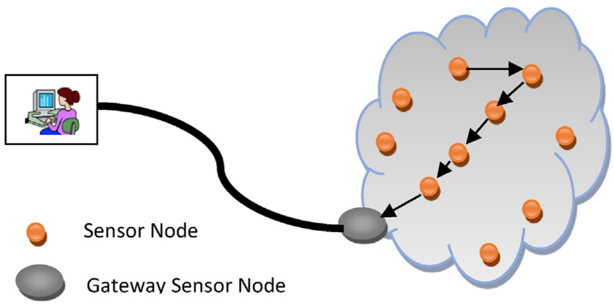

Fig. 1. Wireless Sensor Network [1].

discover an optimal route through source to destination node using routing protocol, which mainly focuses on energy consumption rate during broadcasting information or data. There is a lot of routing protocol available that operates on the basis of energy consumption parameter and some useful routing protocols are analyzed by various researchers, which mainly used for reducing the consumption rate of energy in WSN like LEACH (Low -energy adaptive clustering hierarchy), PEGASIS etc [7]. The PEGASIS routing protocol is most effective routing protocol in WSN due to their nature PRGASIS has an advantage that it has less transmitting distance as compared to LEACH and other routing protocols because it forms a link among the sensor nodes so that every node can transmit and receive information or data to their closest neighboring node [8].

1.1. PEGASIS routing protocol

PEGASIS ("Power-Efficient Gathering in Sensor Information System") is a chain based hierarchical energy efficient routing protocol. It works on the principle of greedy chain algorithm. In this approach, the fastest sensor node is selected which is linked to the nearest node [9].

Fig. 2 represents the greedy chain algorithm for five sensor nodes namely, 1,2,3,4 and BS. In Fig. 2 Node-1 is at the farthest distance from the BS (Base station) [10]. The neighboring node of Node-1 is Node-2 and Node-4. The sensor Node-1 is linked to Node-2, this is due to reason that distance between Node-1 to Node-2 is comparatively less as compared to Node-1 to Node-4. Likewise, Node-2 is linked to Node-3 and Node-4 is linked to Node-4 and so on. At last, Node-4 is connected to the BS. In case of failure of a node due to any reason within the network, for an example, Node-3 is failed due to some reason than Node-2 passed data to Node-4. In PEGASIS, sensor nodes receive data or information from the previous node and fuse their own information to create a single packet and forward that packet to the neighbour node [11].

2. Related work

Nayak, and Vathasavai [17] in their research used fuzzy logic for the aimed purpose and have proved well organized results, the existing work [17] limit in two major ways and the first one is that as fuzzy logic is a rule-based architecture system and with the increase in the network size instructions are added in the network but with a network like MANET, WSN fuzzy logic could possibly contain hundreds of instructions as a result the targeted architecture may get more complex. The projected work streamlines the use of firefly optimization algorithm [18]. whereas this algorithm is very appropriate for the small area optimization problems.

The next issue with WSN is to improve the path selection with distortion in the network. Cluster head selection in case of distortion in the network, battery discharge issue or any other network problem, in such situations there is no substantial way out for the selection of cluster head. The proposed model has listed out this matter very seriously and futured many other possibilities. Keeping the proposed model in consideration the instruction set/rule set will employ the model of Artificial Neural Network for finest cluster head selection with respect to the lifespan of the network. Artificial Neural Network is the arrangement of decision sets. Which comprises of essential elements for parallel procedures. Artificial Neural Network represents a pattern and results an arbitrary 'guess' for it which in turn look for the definite answer and make the suitable modifications to its adjoining weights. The proposed framework is a combination of three structure (1) Grid -based optimal clustering algorithm powered by firefly algorithm for CH selection (2) Route optimization using PEGASIS (3) Distortion free communication based on the artificial neural network (ANN).

Fig. 3 Represents the number of sensor nodes placed on a network with various x and y location. The node marked in dark red box represents CH with no limitation of the searching area. This is the initial step and this process consumes alot of energy to search an appropriate node for the transmission of data [12]. In this research work, to overcome this problem, we design a grid-based network as shown below in Fig. 4.

The entire network area is divided into 12 equal parts, having length*width is 200 m*200 m. The node encircled by the green colour has a limited search area represented by a red line and hence the energy consumption rate will also be reduced. Now, the next objective of this research is to select appropriate CH within the selected area [13]. The author **Nayak et al (2017)** used fuzzy approach for the selection of CH. Fuzzy Logic works on the set of rules which is one the major problem with fuzzy logic therefore, if in the network, any variations occur, rules are added on the network. The rule set used by the author **Nayak et al (2017)** is shown below in the Fig. 5.

In this way, there are thousands of rule added to the network, which makes the network more complex. To overcome this problem swarm inspired optimization algorithm named as "Firefly algorithm" is used. Firefly algorithm used flickering behavior to attract other flies, normally by transmitting a message to the opposite sex [14]. The steps of firefly algorithm are listed below:

1. Fireflies belongs to the category of unisexual species, and all unisexual fireflies can be easily attracted by other fireflies.
2. The attractiveness between the fireflies is inversely proportional to their brightness and fireflies with less brightness are attracted by the

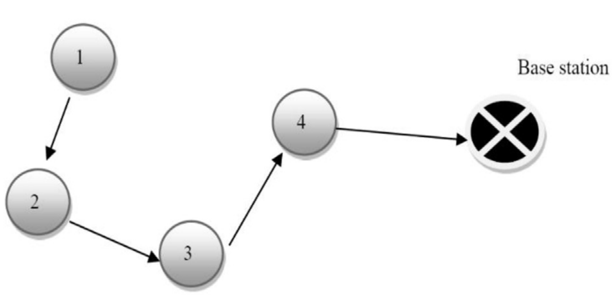

Fig. 2. Greedy Chain Algorithm [9].

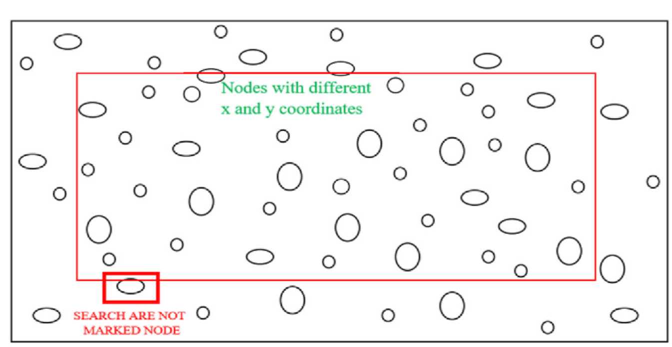

Fig. 3. Non-grid-based architecture [12].

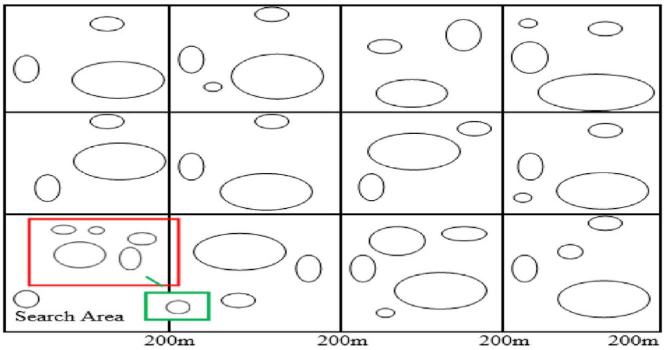

Fig. 4. Grid -based search area [13].

flies with more brightness. With the increase in distance between the fireflies the intensity of light starts decreasing.

3. In case if no firefly is brighter than the given firefly, it starts moving randomly. The Objective Function is linked with the Brightness of Firefly

Distortion free communication based in artificial neural network:
Where W1, W2, W3, …Wn are Weights and.
X1, X2, X3, …Xn are Inputs.
The general architecture of neural network is shown in Fig. 6.

ANN is a classification algorithm that consists of a number of elements connected in parallel. Weight is used to adjust the neurons in the network so that one can obtain desired output [15,16].

3. Porposed modelling

In order to deliver the message to the Base Station (BS) a chain like structure is developed for routing information in WSN, which results a well-organized categorization of every single node in the network. The previous researches show that the network lifespan and energy effectiveness can be significantly enhanced through clustering approach and give valuable scalability to the system. It will improve the power control and propagates the reuse of bandwidth for enhanced resources distribution. Whereas the single hop communication burdens the gateway with the increase in sensors density. It is very clear that the selection of the area is very important just like the selection of the cluster head. Here in this segment, we will discuss the methodology of the projected work along with the algorithms used to achieve the better results is discussed in detail and shown in Fig. 7. The steps used for the proposed work are defined below [19].

Step (1) A wireless network with ‘n’ number of mobile nodes is designed and are positioned with dissimilar x and y co-ordinates.

Step (2) The wireless network is split into twelve equal sectors.

Step (3) Utilization of Firefly algorithm is done for the suitable choice of the cluster head (CH) selection.

Step (4) PR-PGASIS is enrooted for the best route selection between the source node and destination node for the transmission of data.

Step (5) In order to store the data into the neural network, trained neural network architecture is used.

Step (6) Apply Active Distortion Control Artificial Neural Network (ADC-ANN) in case of distortion in the network due to node failure, battery discharge problem or due to any other prevailing issues in the network to categorize distortion and to analyse the performance parameters. Next establishment of route using Proficient Routing based Power Efficient Gathering in Sensor Information System (Proficient-Routing based PEGASIS) for the transmission/receipt of data.

Step (7) In case if the simulation process is complete then stop, else establish the route and start data transmit/receipt.

Step (8) Finally analyse the performance parameters.

3.1. Grid development

The detailed flow chat demonstrating the whole process carried out in this research paper is shown in the Fig. 7. In this approach, the geographical area is divided into 12 equal regions formulated in the shape of grids/sectors. Whereas the grid-based routing is primarily depending upon the actual location of the node. The process to divide the

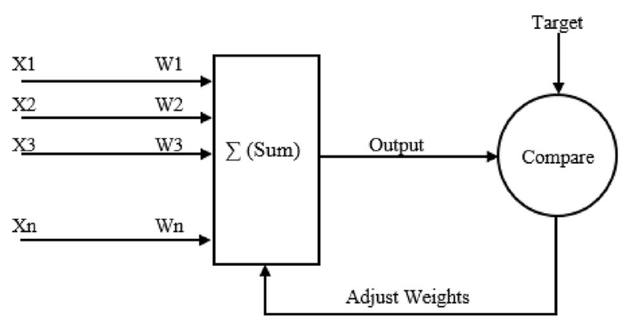

Fig. 6. Structure of neural network [14].

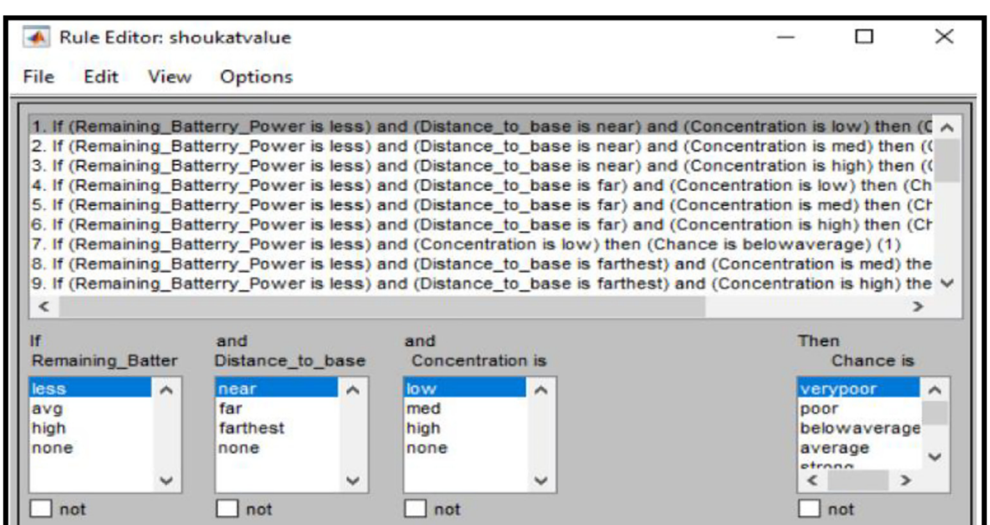

Fig. 5. Rule set [13].

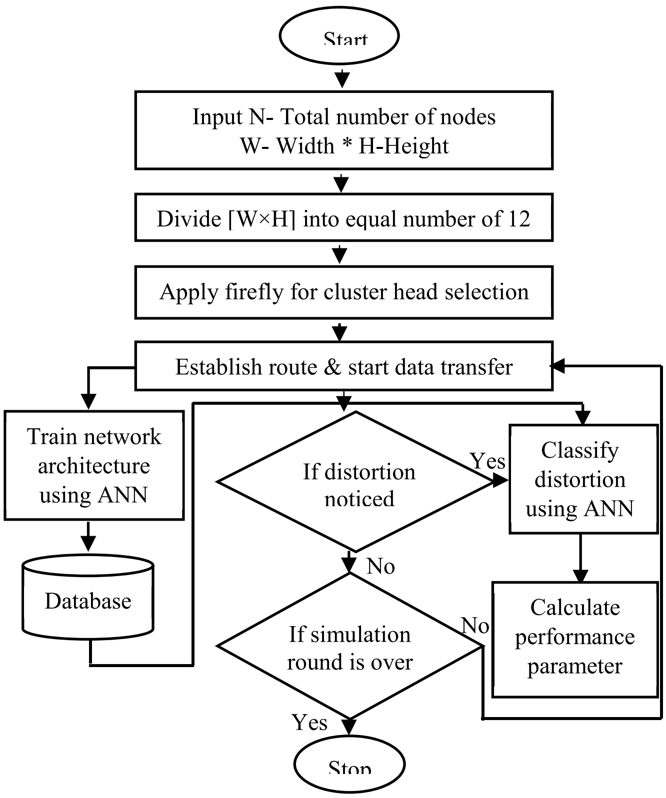

Fig. 7. Flow chart of the proposed work.

area into grid (square form) is continuing as long as the coordinate node left with no energy. The selection of grid is done primarily on the basis of distance from the active node and on the basis of residual power.

The two-dimensional (2D) WSN are split into equal regions based on Grid Routing Protocol as shown in the Fig. 8. The grid may consist of some nodes or may be empty. By knowing the exact location of the grids and sensors node on the basis of clustering algorithm, the total amount of energy spent by every single node can be kept for future use. There fore in order to evade congestion for the cluster head selection the firefly algorithm is used and for routing of data PR-PEGASIS algorithm is used to improve the optimized route within the cluster zone and instead of transmitting the data directly to the BS it will sent the data to the CH [20].

3.2. *Firefly algorithm*

For the selection of appropriate CH, the Firefly algorithm is used and hence utilize the battery power of the sensor node. In firefly we have considered three parameters for the selection of CH, Distance, Energy and Concentration. Average Distance (Δt_1-average distance with in a cluster w.r.t BS for all the nodes), Average Energy (Δt_2-average amount of energy with in a particular cluster for all the nodes) and Average Concentration (Δt_3-average concentration with in a particular cluster for all the nodes) is calculated for each cluster to check for suitable CH in the cluster. For any node to be a cluster head it must fulfil the Fitness_Function condition. The Fitness Function checks for all the node from a particular cluster for its average distance must be less than its distance from the BS, Energy and concentration must be greater than the average energy and average concentration [21]. The CH selection using firefly algorithm is shown in Fig. 8. The Pseudo Code used for the selection of Cluster Head is shown in Algorithm 1 with all the input parameters.

The Expression for Fitness_Function is

$$\text{Fitness\_Function(FitFun)}\begin{cases}1 \text{ if } \ t1 < \ \Delta t1, \ t2 > \Delta t2, \ t3 > \Delta t3 \\ 0 \text{ Otherwise}\end{cases} \quad (1)$$

Cost Function (Cost): The actual amount of energy essentially required by a node for transmitting/receiving data to/from other nodes/ Cluster Head/Base Station is determined by the Cost Function (Cost).

The firefly in the algorithmic from is written below.

Algorithm 1. Firefly.

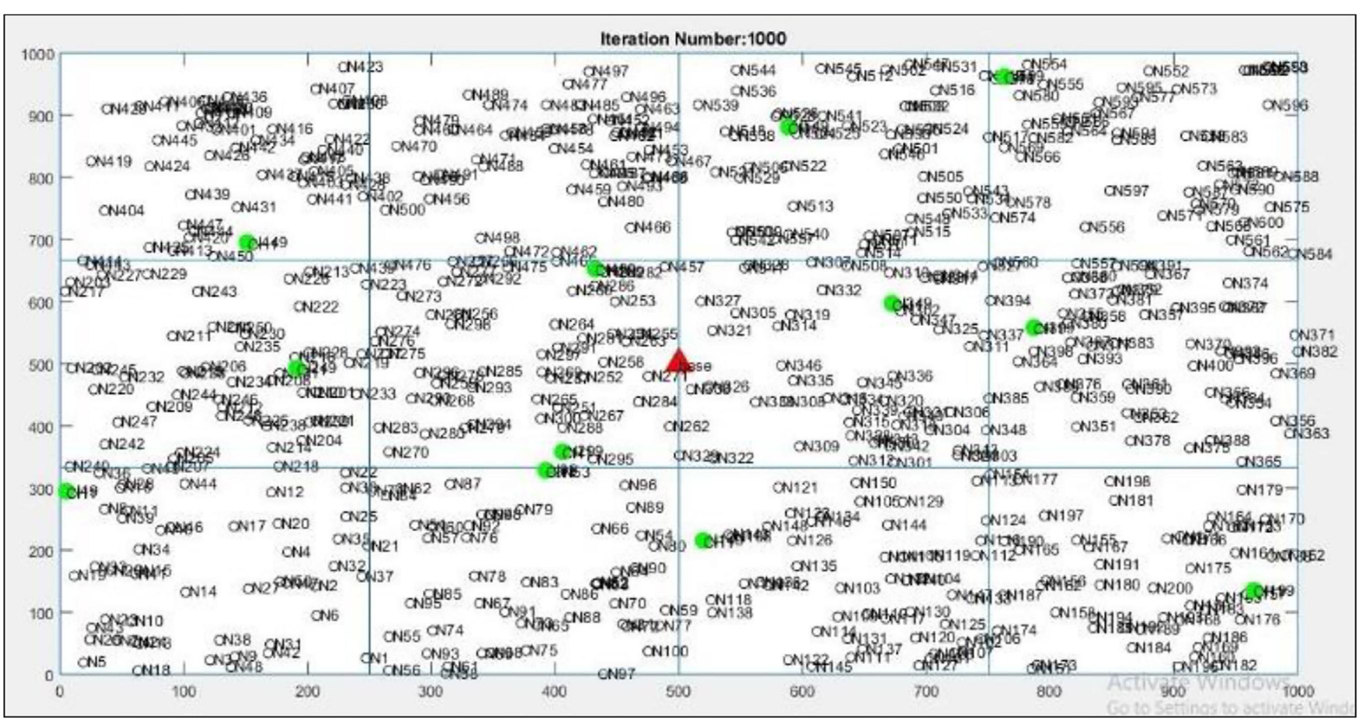

Fig. 8. Cluster Head Selection using Firefly.

***Input**: Properties of Nodes*
***Output**: Cluster Head (CH)*
***Initialize Firefly parameters** - Problem Size (P)*
- Population Size of Firefly(Pop)
- No. of Iterations (In)
Define fitness function (FitFun) and Cost Function (Cost)
For (i=0 to In)
For(j=0 to P)
For all Pop
Calculate the cost of P and find P_{best} Cost
If Cost(P)< Cost(P_{best})
Update light intensity data = U_{LI}
***End** //Enf If*
***End** // End For*
***End** // End For*
Best Node = Sort(U_{LI}, FitFun)
Select best node as Cluster Head (CH)
End
***Return**; Cluster Head (CH) = Best Node*
End

3.3. Active distortion control ANN (ADC-ANN) algorithm

In this research study, Active Distortion Control ANN is used to provide the best Cluster Head (CH) by detecting the occurrence of distortion in the network. The Active Distortion Control ANN is used for detecting distortion if any in wireless sensor networks (WSNs) and take appropriate steps for prevention. Active Distortion Control (ADC) is the procedure with which the sensor nodes in the deployed field can recognize their own position in the wireless sensor network. ADC in WSN plays a critical part in instigating numerous applications such as environment management, agriculture management, disaster management, and healthcare management. Artificial neural network based Active Distortion Control (ADC) makes the Training Data set (T) while deploying the network and formulate the Target data Set (G) to check for any kind of distortion in the network. Before transmitting any kind of information over the network, ADC ANN first check whether there is any distortion in the network by analysing the transmitted data with the Target Data. In case of any kind of distortion like Suspicious Node, Distortion due to transmission. Channel, Energy loss due to battery discharge problem, Node Death the ADC will check for a new Cluster Head (CH) which will eliminate the node/transmission channel responsible for distortion in the network. Active Distortion Control ANN classify the input data and compare it with the trained data to find out if there any distortion in the network. Based on the resultant observations the ADC_ANN classifier will select the CH selection procedure using Firefly algorithm with the following assumptions.

1) If distortion occurs due to suspicious node/dead node, remove the node from the List of all the nodes and perform CH selection using Firefly Algorithm with updated List of Nodes.
2) If distortion occurs due to low energy level of a node, remove the node from the Sorted_List of nodes and perform CH selection using Firefly Algorithm with updated List of Nodes.
3) If distortion occurs due to energy loss/noise in the transmission channel, eliminate the route for transmitting/receiving data and form a new optimized route/chain using **Proficient-Routing based PEGASIS** (PR-PEGASIS) protocol.

The Pseudo Code used to control Distortion in the WSN is shown in Algorithm 2 with all the input parameters. The newly elected CH will get the newly optimized route with **Proficient-Routing based PEGASIS** (PR-PEGASIS) protocol.

Algorithm 2. ADC-ANN.

***Input**: Network properties as a Neurons (N), Target (G), and Training Data (T)*
***Output**: Route Discovery for the Best Node.*
Initialize ANN with parameters
- Data Division: Random
- Epochs (E)
- Training Techniques: Levenberg Marquardt (Trainlm)
- Neurons (N)
- Performance parameters: Validation Points, Mutation, Gradient, and MSE

For each set of T
Make_Group = Types of Training Data
End
Initialize ANN using Make_Group and Training data
Net = Newff(T,G,N)
Train the system as per requirements and set the training parameters according.
Net = Train (Make_Group, Training data, Net)
Set_Class = simulate (Net, Single node properties)
If Set_Class = True
Best Node = Simulated Node
End
***Return**; Best Node*
End

The working model of the Neural Network is analyzed on the basis of performance parameters like MSE (mean square error), mutation, gradient and gradient failure.

The Training-set of ANN will be done under simulated situations where all the possibilities are taken care. All the parameters are checked and experimented using MATLAB (nntraintool) to train the network. The neural network take properties of the node as input data for training the network. The parameters that are considered for training the model are epoch, time, mean squared error (mse), gradient, validation and mutation. The data division is done using random (**dividerand**) function and according to **Levenberg-Marquardt** optimization, the **trainlm** is a network training module that is used to apprises the weight and bias values. In MATLAB toolbox, **trainlm** is one among the fastest back propagation algorithm, and is extremely suggested as a primary choice administered algorithm. The Fig. 9 represents the training of ANN. A single neuron is forwarded to the output layer through a single layer. In the hidden layer biasing and weight adjustments is performed to obtain the desired neurons at the output layer. The Fig. 10 defines the MSE value measured for the trained ANN structure. The best value of ANN is represented by the green circle, which is near to zero. This means that ANN is trained with minimum error and hence provide accurate results during testing process.

The Fig. 11 characterizes the training set of ANN structure. The validation of optimized features obtained from the firefly algorithm is checked by the ANN algorithm maximum for 6 times. This will provide the valid data that denotes the accurate property of the node. ANN is a gradient based technique and validate the training data on the basis of mutation. The validation state is known as the change in state, which is used to validate the training data.

3.4. Proficient-Routing based PEGASIS (PR- PEGASIS)

As shown in Fig. 12 with chain based mechanism used for routing data, PEGASIS is considered as an eminent routing protocol with the major idea of communication to their nearest neighboring nodes. The head node is considered to be a substitute node which in turns used to

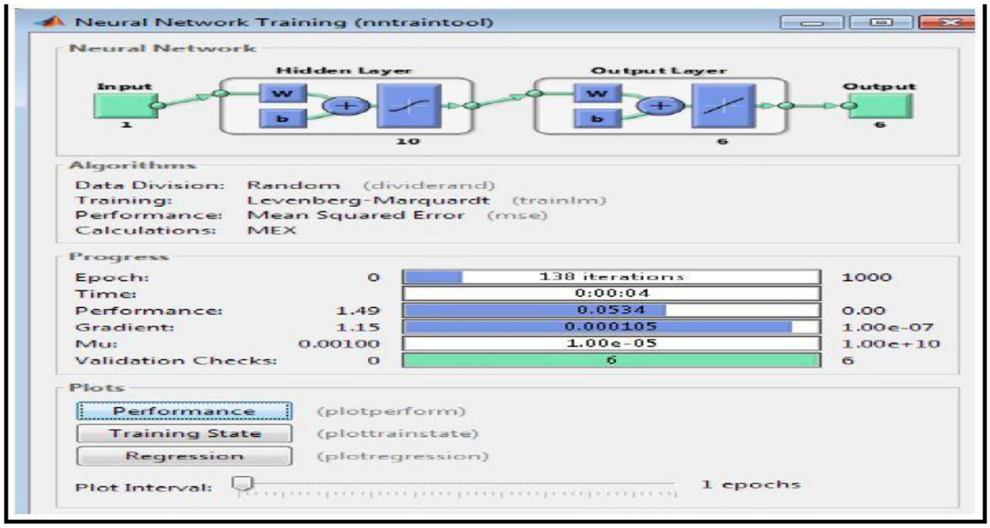

Fig. 9. Training model of ANN

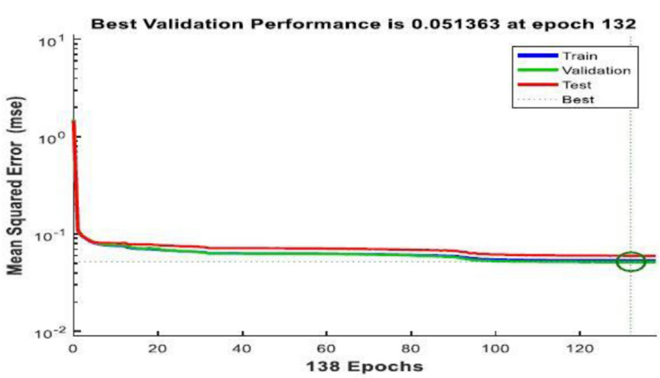

Fig. 10. Mean square error (MSE).

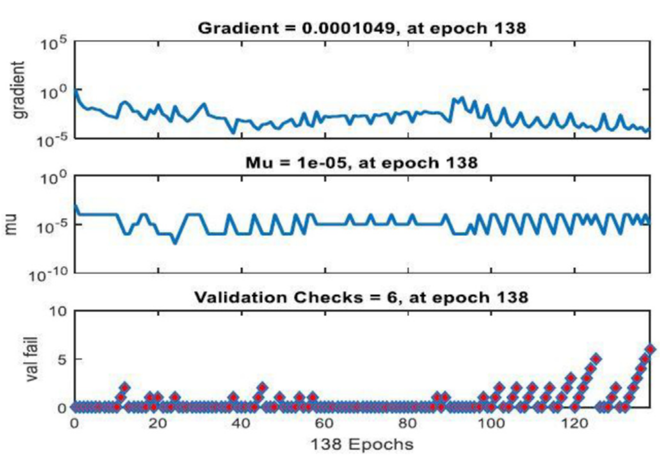

Fig. 11. Training state.

forward the data towards BS. In PEGASIS, the position of the sensor node is arbitrary and each node in the network has the competency to sense data, combine data, and correspondingly forwards the load to the cluster head. As in PEGASIS the chaining of linked nodes is completed with respect to the locating of each node and greedy algorithm is used to link the nodes [22].

PR-PEGASIS protocol works to optimise the route for transmitting data among the CH belonging to various clusters till data extents up to the Base Station (BS). PR-PEGASIS works in both the situations whether there is any distortion in the network or not. PR-PEGASIS forms the route/chain depending upon the **List-DT** of all the node having data to transmit over the network. The basic feature of the PR-PEGASIS is that it avoids the formation of long chain which results the consumption of more energy and decreases the lifespan of WSN. The formation of chain may occurs in the following locations in the wireless sensor network as T-top, D-down, R-right, L-left, TR top right, TL-top left, DR-down right, DL-down left, w.r.t Base Station.

Fig. 12 illustrates the formation of chain/route for broadcasting of data sects/packets to the Base Station through Cluster Heads centred on the working of PR-PEGASIS algorithm. All the green colour nodes shows the cluster head (CH) in the respective clusters. The chain/route formation for transmitting data starts from node Id- ON449-ON208-ON83-ON299-BS-ON349-ON504-ON589 represented with the help of red line.

Algorithm 3. PR-PEGASIS.

Input: *Properties of Nodes, Distance from CH to Base Station (List_CHB), Distance between the nodes and CH (List_ CHN)*
Output: *Best Chain Route (BCR) for Data Transmission*
Initialize parameters *– List of CH to transmit data (List_DT)*
IFall the elements of List_DT lies in one quadrant
Sort the List_DT w.r.t BS
Return: *Sorted List_DT as BCR*
Else
Forall the elements of List_DT
Select two farthest CH in opposite direction w.r.t BS as (T,D,L,R,TL,TR,DL,DR)
Sort List_DT w.r.t BS
Arrange the elements from both directions w.r.t BS
Return: *The arranged List as BCR*
End
End

4. Results and discussions

4.1. Hardware and software requirements

For the execution of the projected study the hardware and software requirements are as discussed below.

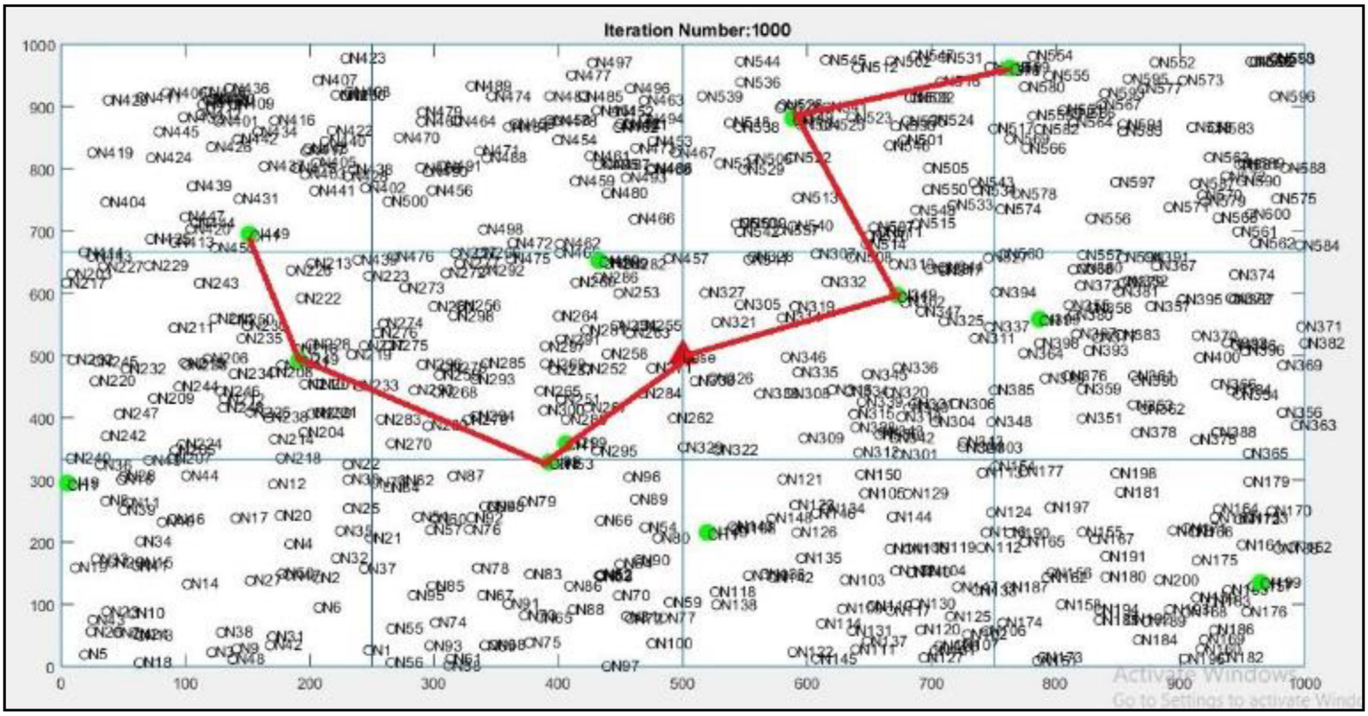

Fig. 12. Route formation using PR-PEGASIS.

a) Hardware requirements

The least hardware items essential for the simulation of the proposed method are.

1) Minimum 4 GB RAM
2) Minimum 1 TB Hard disk (with the increase in memory the performance of the model gets better)
3) I3 Processor or above
4) CPU 32 bits or above

b) SOFTWARE REQUIREMENTS

The least software essential for the simulation of the proposed method are.

1) Windows 7 Operating System or above
2) The software required to simulate the proposed model is MATLAB, the proposed model is codded in MATLAB 17a.

4.2. Experimental setup

MATLAB 17a simulation tool is used for the implementation of the proposed work.

MATLAB 17a integrates all the important features like visualization, computation and programming in a very easy to use/handle environment where all the difficulties and their expected explanations are articulated in familiar mathematical notation. The major advantage of using MATLAB 17a, as it provides an interactive environment for designing, iterative exploration and problem solving. The proposed work prolongs the WSN's lifespan with respect to the following parameters Throughput, PDR, Energy Consumption and Remaining Battery. We have simulated a wireless sensor network in a grid form with 12 regions where nodes are deployed randomly. 2000 nodes are deployed over an area of 1000*1000 square meters in 12 regions. Where each node has a unique identity number as ON1, ON2, ON3………ON2000.

4.3. Simulation parameters

S.No	Parameters	Values
1	Initial Energy level of a Node	1 J
2	Number of Nodes	2000
3	Clusters	12
4	No Iterations	1000
5	Area	1000 m^2
6	Transmission Range	150 m
7	Data Packet size	500 bytes
8	Mutation rate	0.003
9	Crossover rate	0.7
10	Energy consumed during transmission and Reception	50 nJ/bit
11	Idle state power consumption	13.5 mW/s
12	Data Rate	10 packets per second

4.4. Comparison of results with existing method

The proposed work prolongs the WSN's lifespan with respect to the following parameters Throughput, PDR, Energy Consumption and Remaining Battery. The simulated results of the proposed work are compared with the existing work of Nayak and Vathasavai [17].

a) Packet Delivery Ratio (PDR)

The calculation of Packet Delivery Ratio (PDR) [24] is centred on the transmitted and produced data packets. In general, PDR is well-defined as the proportion among the received data packets by the base station and the transmitted data packets by the source. Whereas Throughput is the frequency at which information is directed over the network. Situation like when the traffic flow is low in the network and there is good traffic management to control the flow of data, data packets in such situations probably well train up at the transmitting node and on no occasion derive in the network [24]. Whereas individual packets won't make any input to throughput, but never effect the PDR as these data packets won't travel over the network at all.

The Graph shown in Fig. 13. represents the comparison of PDR (Packet Delivery Ratio) with number of iterations. From the simulation results it is practically experienced that the average values of PDR achieved for the existing work and proposed work are 21727 and 25290 respectively. Thus there are is an enhancement of 16.39% in the PDR value of the existing work.

Mathematically PDR can be defined as

$$\text{PDR} = \text{Packet Sent} / \text{Packet Received} \tag{2}$$

b) Throughput

Throughput of a protocol is calculated as the total number of data packets arrived/received at the Base Station [25]. The superiority of the protocol, i.e. its energy and latency effectiveness hinge on the quantity of data acknowledged by the Base Station. The throughput of the network always gets effected due to distortion in the channel or due to suspicious node in the network which in result makes the transmitting node to consume more energy for transmitting the data [25]. The Graph shown in Fig. 14 represents the comparison of throughput values and iterations. The throughput is measured with respect to number of iterations. The Graph clear depict that the throughput for the projected work is higher than the existing work. The average values of throughput measured for the existing work and proposed work are 12.63 and 17.63 respectively. Thus, the throughput for the proposed work gets increased by 39.56% approximately.

c) Remaining battery

The Remaining Battery of a node in the existing work exhausts mainly due to distortion in the channel and large rule set used to form the cluster head in the network and the energy level of the node starts decreasing rapidly [26]. In the proposed work both the issues have been addressed appropriately for the depletion of energy in the network to make the lifespan of the network last for longer time. The rate at which the nodes consumes energy in the proposed work clearly shows that the network life time grows positively. Graph shown in Fig. 15 defines the comparison of remaining battery power obtained for proposed as well as existing work. The red and blue lines represent the value of remaining battery power for proposed and existing work Nayak and Vathasavai [17] respectively. The graph is drawn between remaining battery power and number of iterations as shown in Fig. 15. The average value of remaining battery power for the proposed and existing work for 2000 iterations are 1882 and 1825 respectively. Thus it is proved that the residual power for the projected work is higher than the existing work. Thus there is an increase of 3.16% in the remaining battery power when Firefly and ANN are used in the network.

d) Energy consumption

The energy depletion ideal model used is the first order radio model which is the typical model in the expanse of routing protocol assessment in WSN [23]. Conferring to this work, the energy consumed for transferring and accepting k-bits of data can be calculated as follows.

$$E_{Tx}(k) = k(\text{Eelec} + \varepsilon\text{amp}\cdot d2) \tag{3}$$

$$\text{ERx}(k) = k.(\text{Eelec}) \tag{4}$$

Where, d is the remoteness among the source node and the destination node. *Eelec* and *εamp* are per bit energy intemperance in communicating or reception integrated circuit and energy compulsory per bit meter square for the amplifier to attain satisfactory indicator to all kinds of noise ratio respectively. The total consumed energy can be calculated as follows

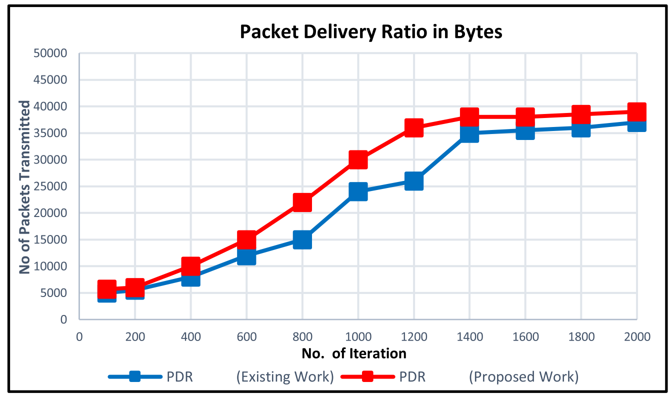

Fig. 13. Comparison of PDR in bytes.

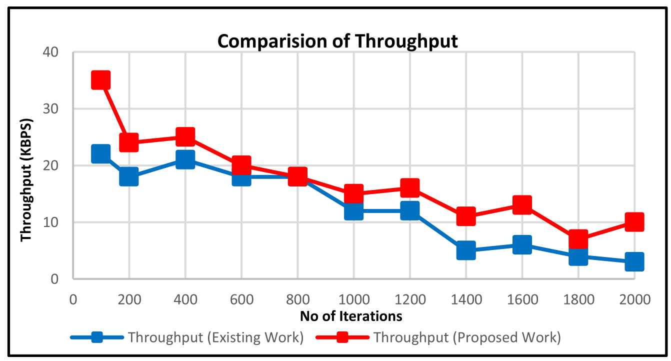

Fig. 14. Comparison of throughput.

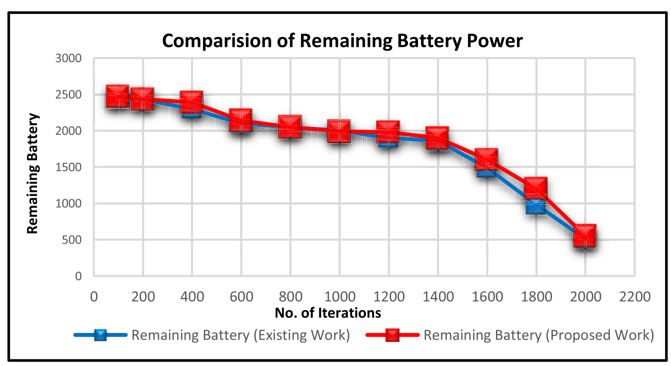

Fig. 15. Comparison of remaining battery power.

$$\text{ET}(k) = \text{ETx} + \text{ERx} = k\,(2\,\text{Eelec} + \varepsilon\text{amp}\cdot d2)\ \ldots\ldots \tag{5}$$

The graph shown in Fig. 16 depicts the energy consumption values measured for existing work as well as for proposed work. The total sum of energy has been spent by the sensor node for detecting the data and forwarding the data to the cluster head (CH) [27]. The energy of a node gets effected mainly due to three major reasons i.e. data transmission, distortion in the network and long-distance communications. Factors like distortion in the network and long-distance communications are addressed using ADC-ANN to make proper utilization of energy of a node. Red line and blue line represent the energy consumption values measured for the proposed and existing work. The average values resulted for the existing work and proposed work are 2.35 and 2.0 individually. Thus, there is a reduction of 17.50% when Firefly and ANN are used in the network.

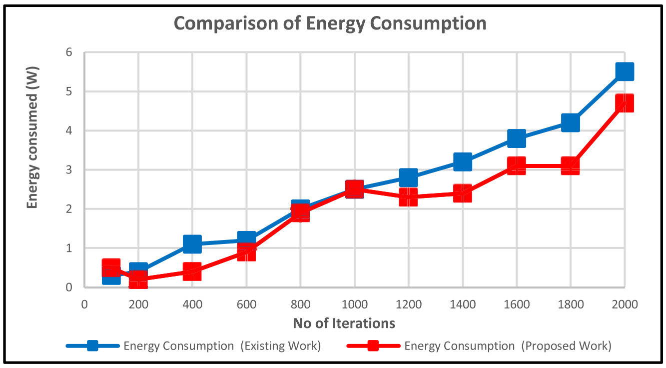

Fig. 16. Comparison of energy consumption.

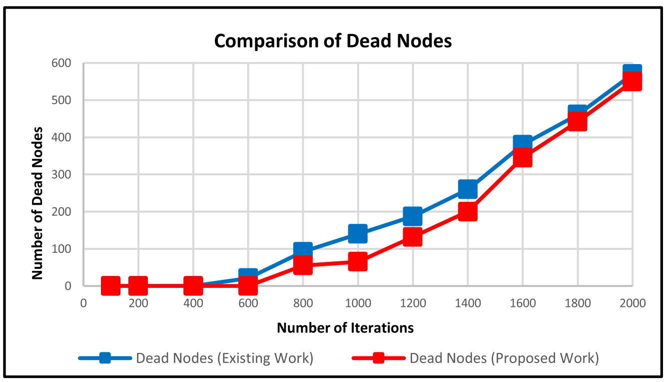

Fig. 17. Comparison of dead nodes.

e) Dead nodes

The proposed methodology depicts the results shown in Fig. 17 for the nodes getting dead in comparison with the existing work. The life-span of a node in the existing work mainly exhausted due to distortion in the channel and large rule set used to form the cluster head in the network. As a result, the nodes start getting dead after a definite time period. Where as in the proposed work we have taken care of both the major issues responsible for the utilization of energy and efforts have been made to make the lifespan of the network last for longer time. The rate at which the nodes consumes energy in the proposed work clearly shows that the network life time grows positively.

The results clearly depict that there is an improvement in the time for a nodes lifespan as shown in the Graph. It displays network lifespan w.r.t variable number of iterations and is used to calculate the competency of the ADC-ANN and PR-PEGASIS in terms of network lifespan.

Whereas in simulation, the total number of iterations are different such as 200,400,600, up to 2000. Performance of ADC-ANN and PR-PEGASIS is assessed with the competency of the network lifespan w.r.t the proportion of the number of CH's among the overall number of sensors nodes in the network. Fig. 17 shows that ADC-ANN and PR-PEGASIS is very consistent with respect to network lifespan because it uses firefly approach to elect the optimal cluster heads unlike the other related scheme used in the existing work. Network lifetime is increased and ADC-ANN and PR-PEGASIS algorithms saves 3.16% of network lifetime.

5. Conclusion

All efforts are made to find out the best ways and means to improve the effective lifetime of the wireless sensor networks in an energy-efficient manner. Energy consumption is the main factor to determine the lifecycle of a sensor node as well as for the sensor network. Preserving battery power for an individual nodes is one among the first issues that extended the planning and operations of the WSN.

- The proposed work minimize the energy consumption rate using PEGASIS routing protocol along with Firefly and ANN.
- Firefly algorithm is cast-off for the selection of appropriate CH within each cluster of WSN and cluster is designed based on grid-based approach to find out the route from transmitting-end to destination-end with the help of a greedy-based PEGASIS routing protocol.
- The proposed simulation is based on performance parameters and distortion if found will initialize ANN to identify the distortion on the malicious node. With the help of ANN, we classify the suitable node according to the route requirement process.
- The experimental results showed the higher efficiency of the proposed work as compared to the existing work.
- The remaining battery power, throughput and PDR obtained from the proposed work is increased by 3.16%, 39.56% and 16.39% from the existing work respectively.
- The energy consumption rate is reduced by 17.50% with Firefly and ANN algorithm.

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Availability of data and material

The datasets generated during and/or analyzed during the current study are available and can be produced on reasonable request.

Code availability

The code is available and can be produced when ever required.

Declaration of competing interest

No conflicting interest and no completing interests.

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