International Journal of Engineering & Technology, 7 (4) (2018) 3430-3436

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International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.14651
Research paper

Enhancement of leach protocol using combinational TSP-AI to improve the lifetime of the network

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Abstract

Wireless sensor networks (WSNs) are come into a demand in recent years, as we seen the wide growth in the lots of wireless devices which includes cellular phones, laptops, washing machines, air-conditioner etc. WSN is a collection of tiny sensor nodes in which one node communicates with other without any physical connection and communication depends on the network lifetime. So the lifetime of WSN is a major factor and need to improve the network lifetime by using the improved routing protocol. In this paper, presents an improved LEACH routing protocol for WSN based on the concept of Artificial Intelligence technique with the Travelling Salesmen Problems approach (TSP-AI). To minimize lifetime dissipation in the WSN, artificial neural network is used to design an improved routing protocol and discover an optimal route for the transmission of data.

Keywords: *Artificial Intelligence; Artificial Neural Network; Base Station; Cluster Head; Co-Operative Cluster Head; CHSN; DCHS; IACC; IECC; LEACH Protocol; LEACH-AI; LEACH with CT; MAC Address; Mobile-Aggregator; Network Lifetime; Packet Delivery Ratio; Particle Swarm Optimization; RSSI; TDMA; TSP; TSP-AI; Wireless Sensor Network.*

1. Introduction

Wireless Sensor Network (WSN) is a collection of sensor nodes, which are connected with each other, and develops the mesh type network. Those sensor nodes are able to do many different kinds of tasks like monitoring and recording the physical conditions of the environment such as temperature, air humidity, pollution, sound, and pressure etc. It also works on military defence and transportation security and so on. Those sensor nodes are wide works in the smartphones and smart vehicles. The research on the WSN has started near on the 1980s but around 2001, the interest has increased in WSN from industrial and research perspectives [1], [2].

In Wireless Sensor Networks (WSN) LEACH is the simple routing protocol which is integrated with clustering. The central goal of the LEACH is to improve the lifespan of the WSN by lower down the energy consumption, which is vital to create and maintain the clusters.

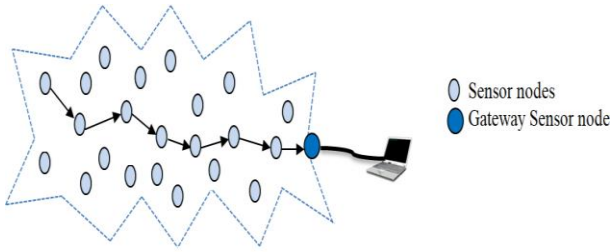

Fig. 1: Wireless Sensor Network.

The WSN has involved in the direction of the future research in Computer Science. The work on the WSN has going on previous generations. In 1970, to obtain a single signal, and a simple point-to-point communication between the nodes, the 1st generation of WSN, has used a hierarchical structure. In the 2nd generation a low power of the sensor, nodes were developed for the WSN, in which every node has independently operated to transform the information with each other and process the data. In 1990, the 3rd generation of sensor network was born, which is used a bus connection method and the controller for collecting the different kinds of data resources. The 4th generation of sensor networks are the pretty much better than the previous other generation sensor networks. Actually, the 4th generation sensor networks have works on the multi-hop and they are self-organized [3].

W.R Hamilton and Thomas Kirkman formulated the Travelling Salesman Problem (TSP) in 1800. The TSP is based on the Hamiltonian cycle in which the graphical structure has been developed by using the nodes, those nodes are connected with each other with the help of weighted edges, and the network has been developed.

Since TSP is an NP-Hard problem in the combinatorial optimization. The generalization forms of TSP are the traveling purchaser problem and the vehicle routing problem. This problem shows an essential role in the operation research and theoretical computer science.

The general mathematical form of the TSP was firstly introduced by the Merrill Flood in 1930 and tried to solve the school bus routing problem and soon after introduces the name as a Travelling Salesman problem [4].

2. Leach protocol

LEACH protocol is a hierarchical routing protocol. This protocol used in the WSN to make the multiple clusters of the nodes and

after that, the Cluster Head (CH) has designated to each cluster so that the CH has reduced the energy consumption of nodes and improves the lifespan of the network. LEACH (Low Energy Adaptive Clustering Hierarchy) [5], [6] can works on the different round by round style and each round has two phases, those phases are written below:

2.1. The setup phase

It has 3 fundamental steps, which are shown below:

2.1.1. Cluster head advertisement

In "Cluster head advertisement", the sensor node which wants to become a CH sends an advertisement packet to the other nodes in the network to inform, that node become a CH on the basis of threshold value T(n). So the formula for the threshold value is shown as below [1], [2]

$$T(n) = \{\frac{P}{1-P*\left(r \bmod \left(\frac{1}{P}\right)\right)}\}, if\ n \in G$$

$$0, \quad otherwise$$

Here n is a node with random number 0 and 1, P is a percentage of the nodes which are become CH, r is a current round, G is a set of those nodes which do not become a CH is the past 1/P rounds, T(n) is a threshold value.
Now, the sensor nodes select the random number v between 0 and 1. Now if the random number is beneath the threshold value T(n) than that sensor node will act as the CH for current round. The threshold also ensures that the nodes which become CH in the past 1/P round will not become a CH in the current round. This will help in balance the consumption of energy.

2.1.2. Cluster set up

In "Cluster setup", the sensor nodes receives the advertisement of CH and then, sends a request message to join the CH and informs that they want sot become member of the cluster under that CH. By the use of this process all the sensor nodes saves their lot of energy by switch off their transmitter and they only turn it on, when they have to transmit something to CH.

2.1.3. Creation of transmission schedule

In "Creation of transmission schedule", every CH makes a transmission or TDMA schedule for each member node which is in their cluster. This schedule is dependent on the number of nodes with in the cluster. Then according to TDMA schedule, every node sends their data in the allotted time period [7].

2.2. The steady state phase

In this phase, the CH which was elected in the setup phase who creates a TDMA based schedule and then assigns a time slot to each node member for the transmission of data. After ending the time period, then the network gets return back into the setup phase to select a new CH.

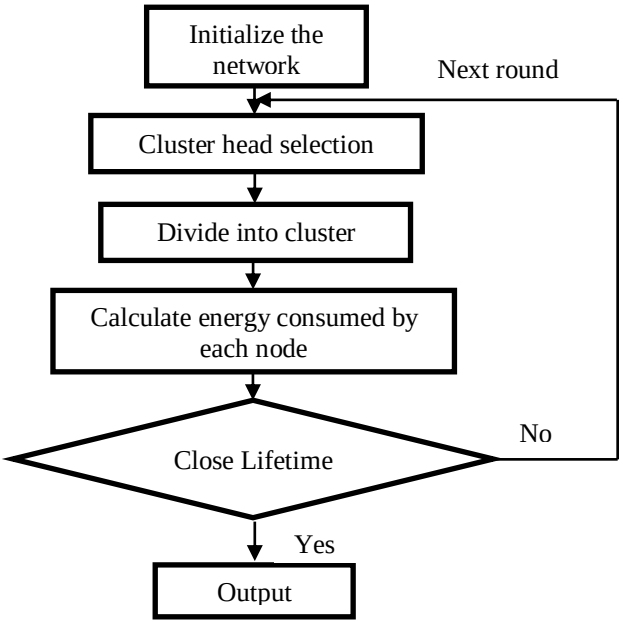

Fig. 2: Flowchart of the LEACH Protocol.

In this approach the CH is not selected on the basis of energy efficient mechanism T (n) of the nodes, these are selected on the basis of pre-determined probability. Figure 2 shows the Flowchart of LEACH protocol [8], [9].

2.3. Advantages and disadvantages of leach protocol

In the LEACH protocol, the CH's are selected at random and due to that, it helps in to reduce the unnecessary consumption of the energy which avoids the premature death of the CH's. As we compare the LEACH protocol which is actually a static routing protocol with the general routing protocol, we have found that, the lifetime of a Wireless Sensor Network has increased around 15% by the use of LEACH protocol.
Now here, we discuss the following advantages [10] of the LEACH protocol, which are shown below:

1) During the transmission of data, the LEACH protocol has carried out the data fusion, which helps into saves the energy and did the reduction in the redundant data.
2) LEACH protocol has adapted the CDMA based mechanism of MAC (Media Access Control) layer. When transmits the data between clusters the LEACH protocol has effectively avoided the interference of the signals. But inside the cluster, LEACH protocol has adapted the TDMA based mechanism of the MAC layer which helps in to avoid the confliction of information which was sent by the nodes, when the nodes are not in their own time gap then the TDMA makes those nodes to sleep, to save the energy.
3) The LEACH protocol has worked on the round wise schedule. Therefore, after the completion of the one round and proceeding to the next round, the LEACH protocol will select the new CH again and then, the novel clusters will develop. Thus, each sensor node in the cluster has the chance to become a CH and evenly distribute the load of the whole network between each node.
4) The CH also helps in; to reduce traffic of the entire network by aggregates the whole data.

LEACH helps in to save the energy of the entire network, as it uses the Single-Hop routing from the sensor nodes to CH. The lifetime of the sensor nodes in a network has also increased with the help of a LEACH protocol.
LEACH protocol also has some disadvantages [11] which we discussed below:

1) In the LEACH protocol, the CH selection is based on the probability basis and the remaining energy of node did not accumulate in the LEACH protocol for communication to BS. If the node is selected as the CH with the low energy

then this could be the result that the collected data could not be sent out.

2) As the running time of the nodes increases, the threshold value T (n) will also increase and due to that it also increases the probability of the number generated by the nodes. So this will make the CH's more than the nodes in the cluster.
3) The CH's and the generated clusters may not be even, in the LEACH protocol because, in the cluster, some of the nodes cannot join and due to that, those nodes will become isolated nodes and waste the network resources. So this problem cannot address well by LEACH algorithm.
4) The LEACH protocol does not consider the trusted node while selecting the CH's, which results that some of the malicious nodes will become a CH's and due to that the distortion has done in the collected data or sending the false information.
5) LEACH protocol randomly develops CH's in the network and did not show any information regarding the number of CH's.
6) The cluster becomes useless, whenever the CH get died and the data which was gathered by the CH never reach to the BS or sink.

3. Architecture of the leach protocol

In this architecture, we have seen that all sensor nodes are connected to the cluster head (CH) and form clusters. Here the Cluster Head (CH) has communicated with the base station (BS). The creation of the CH is based on the Received Signal Strength Indication (RSSI) level of a node, to the BS [12].

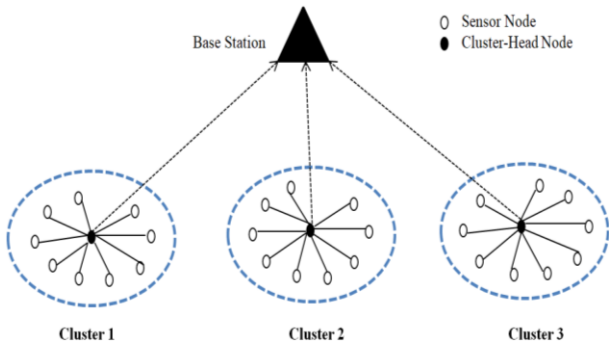

Fig. 3: Architecture of LEACH Protocol.

So all the sensor nodes transmits the information to the CH and CH collects that information then compress it and pass that information to the BS [13]. On the above Fig. 3, we have 3 clusters and each one has its own CH with their sensor nodes in the network to communicate with BS.

4. Related works

Wenliang Wu et al. have introduced an improved LEACH version which is based on the weighted energy of the nodes and their distance ratio. That improved version helps the CH by preventing the energy failure and protects the nodes with less energy and their long distance by allowing the CH to fuse the data before sending the data to the BS. The author introduced the free-space model and the multi-path fading model for circumventing the excessive energy consumption of nodes. The data fusion rate has proposed by the author to diminish the energy consumption of the networks and improve the efficiency in the transmission of data. The improved version of LEACH algorithm has heavily improved the energy consumption of networks and survival rate of the node. It also effectively reduces the loss of energy in the network of the nodes [15].

Asaduzzaman and Hyung Yun Kong have proposed the Cooperative LEACH protocol in this protocol they introduce the cross-layer approach for obtaining the higher order diversity without any loss of spectral efficiency. That protocol works on the round by round fashion and also has the same 3 phases in each round which is same as the LEACH protocol. They introduced the M cluster-heads instead of using one cluster head (CH) in the single cluster. The scheme they proposed here is almost same as the multipath routing scheme for obtaining the spatial diversity at the sink node. The scheme they proposed here is for the M-1 additional CH's which are also known as Co-operative Cluster Heads (CCH's). Afterward, they showed the working of the CH's and CCH's in which if the CH's and CHH's are in the same place or very close to each other than the network doesn't give full diversity gain. For adjusting the transmission power, only those SN's which are in the cluster have to receive the acknowledgments from CCH's. They evaluate the performance of LEACH and Cooperative LEACH by performing the Monte Carlo simulation in MATLAB and found that in local communication the Cooperative LEACH protocol consumes higher energy as compare to LEACH protocol. Here the author also did the comparison of local communication cost between cooperative LEACH and LEACH with a conventional co-operative transmission (LEACH with CT) and found that cooperative LEACH protocol reduces the energy consumption of local communication that is done because of the reduction of CH and CCH's transmission. Now author also did the comparison of the energy consumption and found that the energy increases as the increase in the percentage of the CH's in the long haul network but in the local communication, the energy consumption decreases as the increase in the CH's. So the total energy consumption in a cooperative LEACH decreases up to a certain limit with the increase of CH's. The lifetime of the network increases 10 times more with the use of Cooperative LEACH than the conventional LEACH and that is done because of the gain in the diversity of Long-haul transmission [16].

G.Kannan and T.Sree Renga Raja have introduced the Distributed Cluster Head Scheduling (DCHS) algorithm for achieving the long network life in WSN. In DCHS algorithm the network has divided into primary and secondary tier which is based on the Received Signal Strength Indication (RSSI) of the sensor nodes and the base station (BS). After that, the author has discussed the 3 phases of DCHS and these are IntEr-Cluster Communication (IECC) phase, Data Communication (DC) phase, IntrA-Cluster Communication (IACC) phase. Now author has discussed the simulation results which shows that by the use of DCHS scheme the first node takes maximum number of rounds to dead as compared to the other schemes and the residual energy of the 100 sensor nodes over it applying the 900 runs and found that the DCHS gives the higher level of residual energy than LEACH, HEED and LEACH-C schemes. This shows that the DHCS has provided the better lifetime than that of other schemes. Author has also measure the performance of all the schemes and found that DCHS took 901 number of rounds to the alive the 50% of nodes whereas in others LEACH, HEED, and LEACH-C took 320, 590, 850 number of rounds to alive 50% of the nodes [17].

M. Bennani Mohamed Taj and M. AIT KBIR have introduced the ICH-LEACH and use the simulator called Castalia to compare it with LEACH protocol. The author here discussed the various improvements in LEACH protocol. The ICH-LEACH reduced the consumption of energy by extending the lifetime of network and sending maximum data to sink. Here the author also discussed the different phases of the LEACH protocol and the use of different graphs the author shows that the ICH-LEACH surpassed the original one in terms of the lifetime of the network, consumption of energy and transmission power [18].

Reen-Kamal Kaur Gill et al. has discussed the LEACH protocol with their phases, their advantages and disadvantages and several kinds of attacks, which are done, on this LEACH routing protocol. The author also analyses the old research and observe that lots of work have already done to find the optimal path of the nodes to communicate with one another [19].

Alzahraa Elsayed and Mohamed Sharaf have introduced the (Mobile Aggregator) MA-LEACH to diminish the overload of the CH and use the (PSO) Particle Swarm Optimization to optimize the

trajectory. The author has developed the simulation software to simulate the MA-LEACH protocol and compares their results with clustered heterogeneous sensor networks (CHSN) and also with LEACH with fuzzy descriptors. They developed the network of hundred sensor nodes and each node has the non-researchable battery of 0.5 joules. Furthermore, the author has used an energy model to compute the energy among nodes during communication and also showed the performance of the MA-LEACH protocol with the help of different graphs [20].
LI Xing Guo et al. have discussed the LEACH protocol and works on the energy factor of the LEACH while choosing the CH. Here the author also did simulation and improve the algorithm in various terms like the stability of a network, network lifetime, consumption of energy and collecting the data packets. The author has also discussed the several kinds of advantages and disadvantages of LEACH protocol. Here the author also considers the nodes which have left amounted to available energy, so that avoid those nodes which have low energy to become a CH [21].

5. Proposed solution

The aim of the research is the enhancement of LEACH protocol with AI (Artificial Intelligence) in TSP. The methodology of the work considered is defined below:

5.1. Improvement in leach lifespan

For the selection of CH, the LEACH has used a probabilistic approach in which LEACH doesn't take those nodes which are already become a CH till the recent round r, and gave the chance to the other nodes for becoming a CH in the r+1 round. The algorithm for a selection of the CH does not consider a residual energy of the nodes and the location or distance with respect to BS. So this kind of selection algorithm does not have a capability to ensure the proper selection of a CH and it is also possible that those nodes which have less residual energy or they have a long distance from the BS will become a CH's. So the requirements for the selection of the efficient CH; have considered a distance of the nodes from the BS and also need their residual energy.
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Pseudo-Code of the LEACH Protocol:
j←rand(0, 1)
if T n >j then
Bj= BroadcastMCH( )
Non_cluster-heads = wait(Bj)
Rj= RequstMessage( )
Cluster-heads = receive(Rj)
STj= BroadcastSTT( )
while (Time ≤ STj) do
Cluster-heads = receive(Data)
Endwhile
else Bj= BroadcastMCH( )
Non_cluster-heads = wait(Bj)
Nodes = get(STj)
Cluster-heads = receive(Data)
SFD = sendFusedData( )
BS = receive(SFD)

Here BroadcastMCH() = Message of Cluster heads, BroadcastSTT() = Slot table of TDMA and sendFusedData() = Information of Fused data.

The LEACH is actually designed for those applications which are required periodic detection and they assume that the sensor nodes transmit the data in a (Time-Division Multiple Access) TDMA fashion to their CH's. So the TDMA has increased the consumption of the node's energy. Lots of the applications get activate only on the occurrence of any specific event and then communicate with the BS by sending the required information to the BS.

5.2. Proposed technique

Here, we proposed the technique LEACH with AI and tried to overcome the deficiencies of the LEACH protocol in the TSP. Since AI is also known as the Machine Intelligence which was demonstrated by the machines. The neural network is a branch of the AI which consists of the [3] layers and these are Input Layer, Hidden Layer, and Output Layer. In a neural network, we only concern with input and output layer. We use the neural network to train our network.
On Fig.5.2, we have shown the Flow-chart of our work, which helps in describe our work.
Initialization of the network with n number of nodes.
Selection of CH based on $(k = 2^n - 1)$, where k is the Total number of nodes and n is the number of CH's developed on the basis of nodes in the network.
TSP algorithm has applied on each CH and the simultaneously applied, neural network to train the network.
If (CCH) Co-operative Cluster Head failure is false, then again apply TSP algorithm on CH in the network and simultaneously train is that network with neural network.
If CCH failure is true, then apply AI to find out the new CH, which is an alternative of the old CH.
Stop the process, when the Total iteration is equal to the Last iteration.
Otherwise, again apply the TSP algorithm on each CH in the network.
Now here, Let k = 50, i.e. the number nodes in the network. Therefore after applying the formula $(k = 2^n - 1)$, we get the value (n = 5.642), which is approximate to 6 number of CH's
Now, after the proposed work we are going to explain the result section of our work, in which we discussed the implementation of the LEACH protocol with the AI on the TSP.

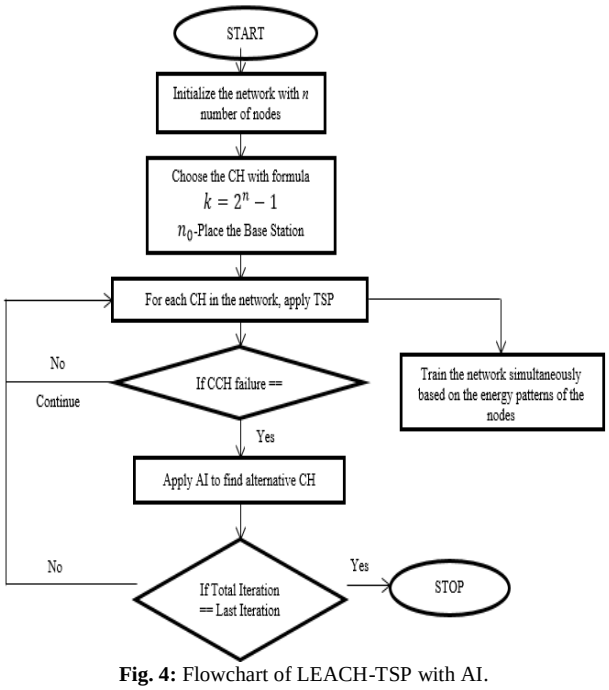

Fig. 4: Flowchart of LEACH-TSP with AI.

6. Results

In this section we have discussed the implementation of LEACH protocol with AI in TSP for the selection of the CH's. We have also discussed the throughput of the network, data delivery rate of the packet and energy consumption of the nodes in the network. After that the comparison between LEACH and LEACH with AI in TSP is drawn and at the end we have found the conclusion on that.

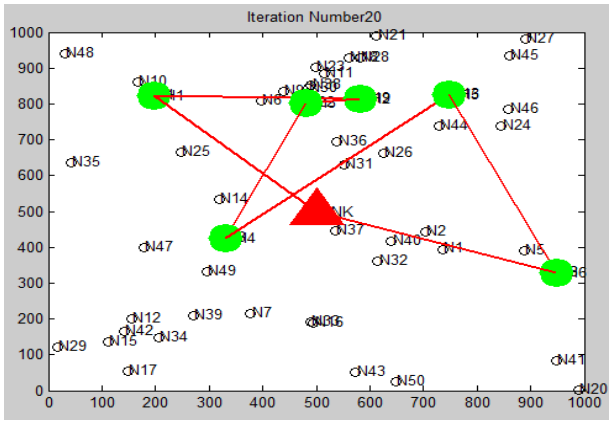

Fig. 5: Communication between Source and Destination.

Here on the X-Y plane, in Fig. 5 we consider the 50 cluster nodes denoted with CN, the green circle is consider as the CH's of the area and the red triangle is a Sink or a BS. After completing the 20 iterations, we found out the above fig.6 where all CH's are communicating with each other and dump the data into the sink.

6.1. LEACH with AI

Here we are discussing the implementation of the LEACH protocol with the use of neural network.

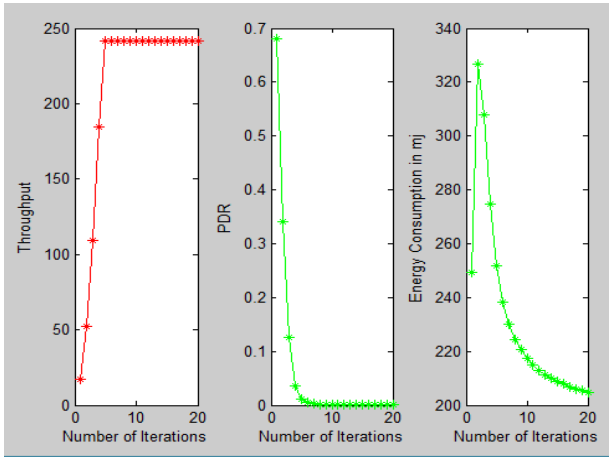

Fig. 6: Computation of Throughput, PDR and Energy Consumption with Hybridization of LEACH and AI.

From the above graphical Fig. 6, we have seen the Throughput of 20 iterations in which it gradually increases around 240 at the 5th iteration and after that it remains constant up to the 20th iteration. On the next graph we have seen that, the Packet Delivery Ratio (PDR) is 0.68 on the first iteration and after that it decreases very fast and on around the 5th iteration it reaches to the 0.02 and around 7th iteration PDR came to 0 and remains to 0 up to the 20th iteration.

Now after that on the 3rd graph the Energy consumption of the CH's are in mill-joules (mJ), So here we seen that the Energy consumption of the CH's are around 330 mJ on the 2nd iteration which is the maximum consumption of the energy but after the 2nd iteration the consumption on the energy make a down fall and it gradually decreases up to 205 mJ until the 20th iteration.

6.2. Train the network

Here we discussed to train the network using AI with the help of neural network.

Now here, from Fig. 7 we have seen the neural network training. So here, whenever the energy of the CH has reduced by the required energy, due to that the CH not able proceed further and pass the data packets then the neural network train the network and find the new CH which is able to complete the remaining task. For the selection of a new CH, the ANN did multiple iterations and selects that node from the cluster as a CH which is having maximum residual energy.

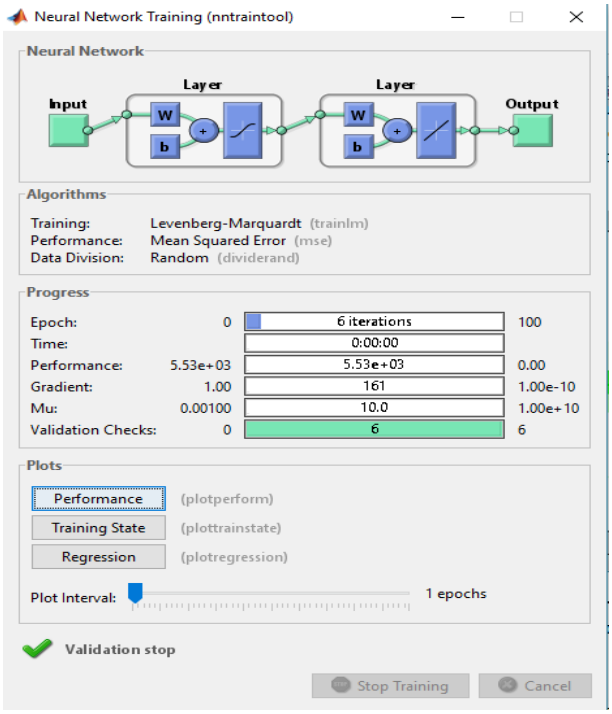

Fig. 7: Train the Network Using ANN.

6.3. LEACH without AI

Here we are discussing the implementation of the LEACH protocol without using the neural network.

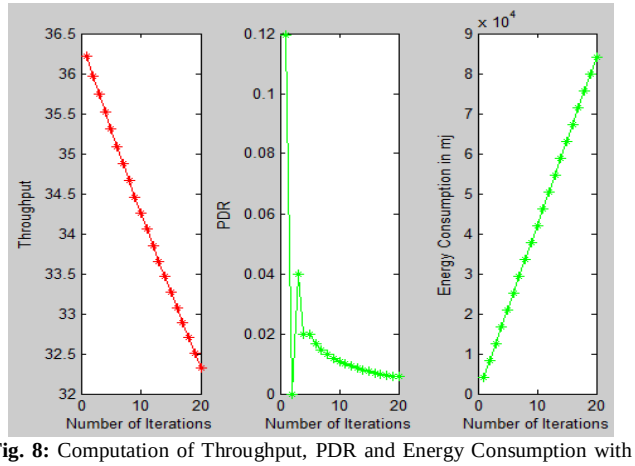

Fig. 8: Computation of Throughput, PDR and Energy Consumption with LEACH.

From the graphical Fig. 8, we have seen the output of 20 iterations; on that the Throughput of the network is around 36.2 on first iteration which is the maximum Throughput. But after that it gradually decreases as the increase in the iteration and on the last 20th itera-

tion it reaches to 32.3. Now on the next graph the Packet Delivery Ratio (PDR) is 0.12 on the 1st iteration which was the maximum ratio of the 20 iterations and after that the PDR make a downfall to reach to 0 and then again increases to 0.04 and on the 3rd iteration it again downfall to 0.02 and in the 4th to 5th it remains constant and after that graph is again decreases in the curved manner and reaches below to 0.01 up to the 20th iteration. On the next graphical figure the Energy consumption of the CH's has increased up to the 8.5×10^4 mJ as the iteration increases.

6.4. Performance comparison between leach and leach with AI in TSP

In this section we did the comparison of their performances between LEACH-TSP and LEACH-TSP with AI. Here on Fig. 9 we have seen the graph between the Throughputs i.e. the Total packets per frame and Total number of Iterations. As we seen from the 1st iteration in the LEACH-TSP; the throughput is around 40 and it remains constant until the 20th iteration. Now we talk about the LEACH-TSP with AI, here on the 1st iteration the throughput is around 20 and after that it gradually increases up to 240 until the 5th iterations and after that the throughput is remains constant until the 20th iteration.

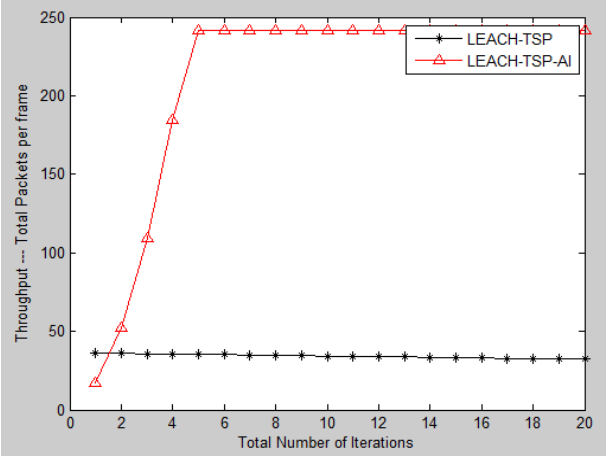

Fig. 9: a) Comparison of throughput for LEACH-TSP and LEACH-TSP with AI.

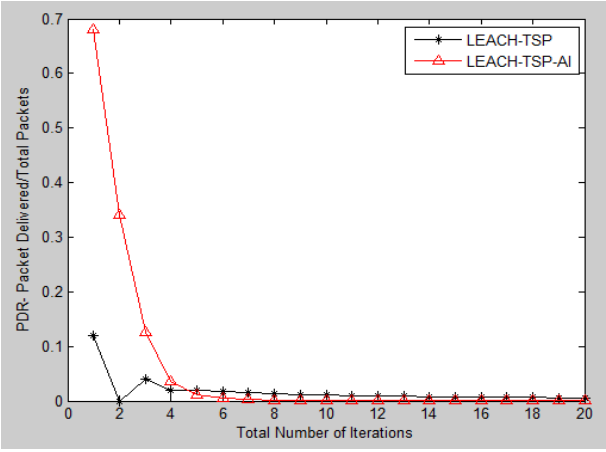

Fig. 9: b) Comparison of PDR for LEACH-TSP and LEACH-TSP with AI.

From Fig. 9 (b) we have seen the graph between Packet Data Delivery Ratio (PDR) and the Total number of Iterations; that on the 1st iteration in the LEACH-TSP, the PDR is above from 0.1 and on the 2nd iteration it's on 0. On the 3rd iteration the PDR is around 0.04, on the 4th iteration the PDR is around 0.02 and remains constant on the 5th iteration and after that the PDR decreases up to 0.01 until the 20th iteration. Now we talk about the LEACH-TSP with AI here on the 1st iteration the PDR is about 0.69 and then the PDR decreases, on 2nd iteration the PDR reaches around 0.35 and on the 3rd iteration the PDR of LEACH-TSP with AI is 0.12 and on 4th iteration PDR is around 0.5 after that PDR of LEACH-TSP with AI has gradually decreased to 0 and remains 0 until the 20th iteration

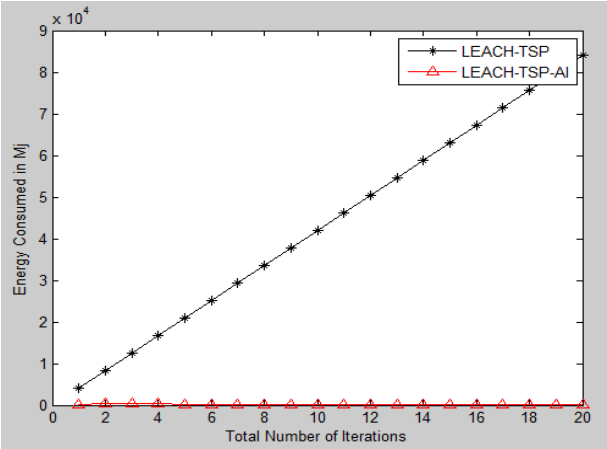

Fig. 9: c) Comparison of Energy Consumption for LEACH-TSP and LEACH-TSP with AI.

Here on the Fig. 9(c) we discuss about the energy consumption of the LEACH-TSP and LEACH-TSP with AI. From the above graph we found that the energy consumption in LEACH-TSP is increased as the number of iteration increases and on the 20th iteration the maximum energy consumption of about 8.5×10^4 Mj. But in the LEACH-TSP with AI we saw the huge downfall in the consumption of energy, on 1st iteration the energy consumption is near about 0 and it is remains constant until the 20th iteration.
Here we discussed the parameter values which are used in simulation, with the help of a table-1 shown below:

Table 1: The List of Parameters, which are used in simulation

S. No.	Parameter	Value
1	Number of nodes	50
2	Number of Cluster Heads(CH)	6
3	Location of Base Station (BS)	500x500
4	Area of a network	1000x1000
5	Number of Iterations	20
6	Total number of Packets	100
7	Energy Consumption	0

7. Conclusion

In this paper, an improved routing protocol is designed based on the concept of artificial neural network along with the travelling salesmen problem approach. This work puts forward improvement programs on the base of LEACH protocol for WSN, and uses MatLab simulation software to simulate in the following aspects: energy consumption, packet delivery rate and throughput. Comparison results show that the efficiency of proposed system is better than the existing work in terms of QoS.
In this paper we make the improvement in the CH's for the traveling salesman problem and introduced the artificial neural network to train the network and resume the process by adding new CH with the remaining CH's in the network, which discover an optimal path for the data transmission.

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