RLEACH-ACO: Revised LEACH-ACO Routing Protocol for Enhancing Energy Efficiency of WSN

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Abstract: Energy efficiency is the critical issue while designing wireless sensor networks. Since the sensor nodes have limited power capabilities, it is required to design protocols to conserve the limited resources of the WSN in order to maximize the lifetime of the network. In this paper, we are presenting Revised Low Energy Adaptive Clustering Hierarchy- Ant Colony Optimization (RLEACH-ACO) routing protocol for enhancing the energy efficiency of WSNs. Performance of proposed approach is evaluated for varying number of nodes, number of rounds and position of base station. Simulation results show that proposed protocol reduces total energy consumption, increases number of packet delivered, reduces the number of dead nodes and provides an optimal route.

Keywords: WSN, Energy efficiency, LEACH, ACO, RLEACH-ACO.

I. INTRODUCTION

Wireless Sensor Networks are wireless network consists of various sensor nodes and Base Station (BS) for monitoring different environmental conditions i.e. temperature, motion, etc. In WSN, lifetime and consumption of energy plays significant role due to limited source of battery which cannot be changed or recharged as the location of WSN is not access by human. Energy efficient protocol performs its operation by using chain based and clustering based protocols like TEEN, APTEEN, LEACH, DEEC, PEGASIS etc. Chain based protocols increases delay when it is used in dense network. So, clustering approach can be considered for reducing energy consumption and thus maximizing the energy efficiency which in turn increases the network lifetime. In clustering approach, Cluster Heads (CHs) are selected and data packets are delivered to base station by using these selected CHs [1]. In this work, LEACH and ACO have been considered to enhance the energy-efficiency of WSN. A brief introduction of these two algorithms is as follows:

i. LEACH

Low energy adaptive clustering hierarchy (LEACH) is introduced by Wendi Rabiner Heinzelman in 2000 [2]. It is one of the most popular hierarchical clustering-based protocols that use random rotation of cluster head to evenly distribute the energy load among the sensor nodes in the WSN for minimizing the overall energy utilization and it termed as Low-Energy Adaptive Clustering Hierarchy (LEACH). LEACH outperforms static clustering algorithms by demanding nodes to volunteer as a high-energy CH and adapting the corresponding clusters based on the nodes that may be selected as CH at a given time. At different time different node has the burden of getting data from the nodes in the corresponding cluster, combining the data for obtaining an aggregate signal and then finally forwarding the data to the sink node or base station. Since, its invention several modifications have been proposed to enhance the efficiency of LEACH protocol [3-5].

ii. ACO

Ant colony optimization (ACO) is introduced by M.Dorigo in 1992. It is based on swarm intelligence optimization algorithm. It uses the positive feedback and distributed computations that involve the study of collective foraging behaviors of ants to find the optimal path among various possible paths connecting the food source to their nest depending upon the pheromone concentration value. Ants secrets a chemical substance called pheromone which is used to connect the path between nest and food source. ACO not only finds the shortest path but also it measures the node energy. This results in increase in the network lifetime [6].

Rest of the paper is organized as follows: Section 2 presents related work in this area, Section 3 explains the proposed work, Section 4 describes the simulation setup, Section 5 presents the results and section 6 concludes the work with future remarks.

II. Related work

As outlined in section 1, various clustering based protocols are proposed in literature. This section presents efforts made by researchers to enhance the energy efficiency of these protocols/algorithms.

Zibouda Aliouat et al. [7] introduced two new hierarchical routing protocols named Well Balanced TEEN (WB-TEEN) and Well Balanced TEEN with Multi-hop intra cluster communication (WBM-TEEN). In WB-TEEN each cluster consists of equal number of sensor nodes for balancing the nodes. Improvement of WB-TEEN is WBM-TEEN in this each node within the cluster communicates with its closest node. This results in minimum use of energy.

Hairong Zhao et al. [8] described an approach for improving the Low Energy Adaptive Clustering Hierarchy (LEACH) for refining the setting up of cluster and route of data transmission. During the formation of cluster a timer is used to make sure of selecting the ordinary sensor node as a

CH. Both single hop and multi-hop hybrid routing is used for data transmission which results in utilization of the energy more effectively. This approach boosts the network lifetime about 15%.

Xia Li, Wang Gang, et al. [9] presented a new concept by combing the improved particle swarm optimization clustering protocol with the inter-cluster routing algorithm named as an adaptive energy-efficient routing protocol (AECRP). It follows two stages as initial establishment stage and stable transmission stage. In initial establishment stage, concern to self-organizing clustering and it selects the CH. In stable transmission stage, data packets are divided into multiple frames in turn each frame contains a range of time slots.

M.A.Hasant et al. [10] proposed a new approach coined as Bio inspired Distributed Energy Efficient Clustering (B-DEEC) protocol as an improvement of DEEC. In this, ABC optimization is used for selecting CH and helps in increasing both the lifetime and throughput of the WSNs. Aim of this scheme is to maintain the full coverage of the network area for maximum time. Initially, initial and residual energy level of sensor nodes is used for choosing the CHs. Protocol estimates the ideal value of WSN lifetime which is used for calculating the reference energy that each node consumes during a single round. It conducts three phase for its operation, namely, CH selection, Finding neighbors or Employed node and Energy comparison or Fitness function phase.

Saad A. Alharthi and Princy A. Johnson [11] presented a hybrid threshold sensitive and two-level heterogeneous LEACH (HT2HL) protocol. LEACH can be made heterogeneous aware in which the nodes are assumed to have different energy levels. This protocol combines the operation of heterogeneous LEACH and TEEN (Threshold sensitive Energy Efficient sensor Network) protocols. Parameters used for performance evaluation are stability period in which the first node dies (FND), network lifetime which gives the number of alive nodes until half of the nodes die (HND) and when the last node dies (LND), the residual energy and data rate over the network (throughput). Threshold is used for reducing the number of transmission which in turn saves energy. In the presented protocol if the CHs are far from the BS than the ordinary nodes can directly transmits the data towards the BS and adjust their transmission power on the basis of distance from CHs and the BS.

Walid Abushiba et al. [12] proposed a novel CH-LEACH (Cluster Head-LEACH) for enhancing energy-efficiency and network lifetime. This protocol considers a number of connections in cluster so that CH communicates with base station, however the selection of the CH is based on the number of cluster on the network gird area. This method allows the network to implement the best situation to prolong life time of the network, cluster are formed in different ways in order to avoid the condition that one cluster will contain large number of connection nodes and other not, the maximum number of the CH is chosen in different situation to test the network coverage. Proposed protocol considers a network of nodes in which all the nodes are homogeneous i.e. each node has identical sensing, communication capabilities and equal initial energy. The base station is considered static by assuming two locations first is at the edge of the network and second is at the center of the network field.

Natasha Ramluckun, Vandana Bassoo [13] described a routing algorithm for extending lifetime of the sensors by enhancing load distribution in the network. This scheme is based on the chain-based routing technique of the Power Energy Gathering in Sensor Information Systems (PEGASIS) protocol and ACO to obtain the optimal chain. Multi-hop scheme is used for both intra-cluster and inter-cluster communications to ensure that minimum transmission energy is expended. An appropriate CH selection scheme is implemented for proper load balancing. This approach shows superiority in terms of alive nodes left, network residual energy, latency, throughput and load balancing.

III. Proposed Work

Performance of hierarchical routing protocol depends on the formation of cluster and the selection of cluster head. So formation of cluster and selection of cluster head are very important tasks. In this work Revised Low Energy Adaptive Clustering Hierarchy- Ant Colony Optimization (RLEACH-ACO) is proposed. It is the combination of LEACH and ACO protocol. LEACH is used for creating the clusters and selecting the cluster heads (CHs). It would consider node's energy and information about the location for optimizing the best cost by using ACO. LEACH is preferred because it can be used in dense area effectively. Sensor nodes are dynamic in nature and deployed randomly over the sensor field while the BS is static in nature and located at a fixed location. The proposed approach is implemented in following phases:

Phase 1: Formation of Network Architecture- Initially network area is created by deploying sensor nodes randomly and base station (BS) at fixed position.

Phase 2: Formation of Clusters- Sensor nodes have been combined together to form clusters randomly on the basis of node energy by using LEACH.

Phase 3: Selection of CH- For selecting the sensor node as a CH, number of rounds is performed by LEACH protocol. The sensor nodes which are alive within each cluster and possess the highest residual or total energy is selected as the CH for that cluster. After the selection of the CHs, distance between the BS and CHs is estimated by using equation (1):

$$DBS = \sqrt{(x\ coordinate\ of\ BS - L\ of\ field)^2 + (y\ coordinate\ of\ BS\ - W\ of\ field)^2} \qquad (1)$$

Where DBS is distance from base station, L is length and W is width of the sensor field.Probability of electing a sensor node as a CH is given by equation (2)

$$\mathrm{P} = \frac{\mathrm{p}}{(1-\mathrm{p}*\mathrm{mod}\left(\mathrm{r},\mathrm{round}\left(\frac{1}{\mathrm{p}}\right)\right))} \qquad (2)$$

Where P is probability, p = 0.1 and r is number of rounds.

Phase 4: Selection of optimal path -An optimal path among CHs as selected by the LEACH is established by ACO and provides the best cost. Best cost is the length of optimal path among CHs and BS. For this packets are launched from the CH moves through neighbor CH and reach the sink node or BS. After the launching of packets, the next CH is selected on the basis of probabilistic decision rule given by equation (3):

$$P_{ij}^{k} = \begin{cases} \frac{([\tau_{ij}]^{\alpha}.\ [\eta_{ij}]^{\beta})}{\sum_{s\epsilon allowed_k}[\tau_{is}]^{\alpha}.[\eta_{is}]^{\beta}} & j\epsilon allowed_k \\ 0 & otherwise \end{cases} \qquad (3) \qquad [6]$$

Where P is the probability, $(i,j)$are total number of sensor nodes,τ is the pheromone value, α is pheromone exponential weight, β is heuristic exponential weight, η is heuristic information matrix. Pheromone update formula is given by equation 4:

$$\tau_{ij}(t+1) = \rho.\tau_{ij}(t) + \triangle\tau_{ij} \qquad (4) \quad [6]$$

Where ρ is evaporation factor, τ_{ij}(t) is pheromone value at time 't' and $\Delta\tau_{ij}$ change in pheromone value and given by following equation:

$$\triangle\tau_{ij} = \sum_{k=1}^{l} \Delta\tau_{ij}^{k} \qquad (5) \quad [6]$$

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k} \text{ if ant } k \text{ travels on edge } (i,j) \\ 0 \quad \text{otherwise} \end{cases} \qquad (6) \quad [6]$$

Where $\frac{Q}{L_k}$ is the amount of pheromone change and L_k is the distance of tour. These equations are used by ACO for establish the best route among CHs.

IV. Simulation Setup and Performance Parameters

i. Simulation setup

Table 1 shows the simulation set up used in this work to evaluate the performance of proposed RLEACH-ACO algorithm. The sensor nodes are randomly distributed in 100 X 100 square meter sensor field. Base Station is static and located at (50, 95) coordinates in the sensor field. Initial energy of each sensor node is 0.5 J, probability of CH selection is 0.1, free space energy is 10pJ/bit, multipath energy is 0.0013pJ/bit. The simulation have been performed and analyzed using performance metrics including total energy of the network, number of packet delivered per round, number of CH selected per round, number of dead nodes, number of alive nodes and best cost. MATLAB platform is used for creating simulating platform for our proposed RLEACH-ACO approach.

Table 1: Simulation Set up

Parameters	**Values**
Number of sensor nodes	100, 200, 300
Sensor field	100X100 Sq.m.
Deployment of nodes	Random
Location of BS	(50,95)
Initial energy of a node	0.5 J
Probability of CH	0.1
Free space energy (E_{fs})	10pJ/bit
Multipath energy (E_{mp})	0.0013pJ/bit
Data aggregation energy	5 Nj
Packet length	6400 bits
Transmission energy (ETX)	50 nJ/bit
Reception energy (ERX)	50 nJ/bit
Number of ants	40
Number of iteration	100
α,β	1
P	0.05

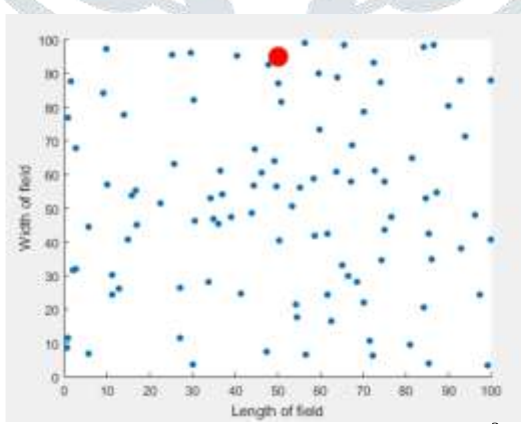


Fig.1: Deployment of 100 nodes in 100X100 m^2 area

ii. Performance parameters

- **Network lifetime:** Lifetime of the network is defined as the operational time of the network for which it is able to perform the communication.
- **Number of packet sent:** Number of packet sent are the sensed data or information which is transmitted by sensor nodes to base station**.**
- **Total energy:** It is the energy which is contained in the sensor nodes within a sensor field. This energy is used by nodes to forward the data towards BS.

- **Cluster Head (CH):** CHs are selected on the basis of energy level of the sensor node. The selected CH receives the data from sensor nodes and transmits the received data to BS.
- **Dead Nodes:** The nodes that are depleted their energy completely and do not possess enough energy for transmission of data are considered as dead nodes.
- **Alive Nodes:** The nodes that do not depleted their energy completely and possess enough energy for transmission of data are considered as alive nodes.
- **Best cost:** It is the estimation of the distance among the CHs for creating optimal path.

V. Results and Discussions

The proposed routing approach is simulated with variation in the number of nodes, number of rounds and by varying position of the BS. Fig.1 shows the random deployment of 100 sensor nodes and a BS which is located at fixed (50, 95) coordinate of 100X100 sq.m. sensor field. The performance is evaluated by varying the number of nodes, number of rounds and position of Base station. As sensor nodes are deployed randomly, so change in the location of sensor nodes may vary simulation results slightly. To overcome this, every round is performed ten times and average of results is plotted.

i. With variation in number of nodes and number of rounds

In this section, performanc of RLEACH-ACO has been evaluated for variation in number of nodes (100, 200,300) and variation in number of rounds (100-2000).

Fig.2-9 shows number of packets sent, total energy, number of CH selected, number of dead nodes and alive nodes, optimal path among selected CH and best cost for 100 sensor nodes and 200 rounds.

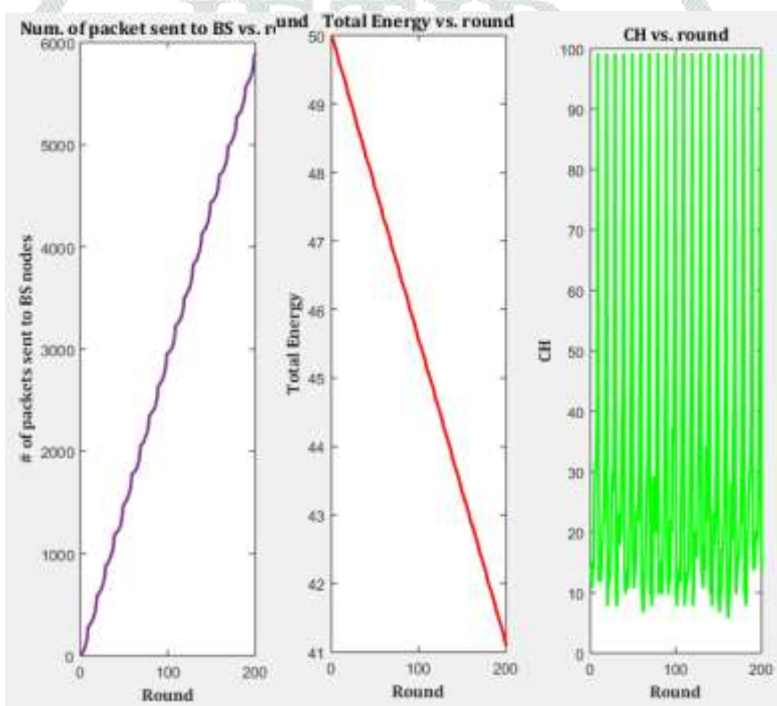
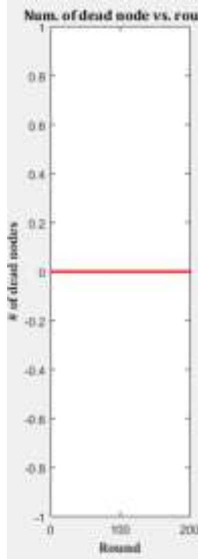


Fig.2 No. of packets sent to BS Fig.3 Total energy Fig.4 No. of CH selected



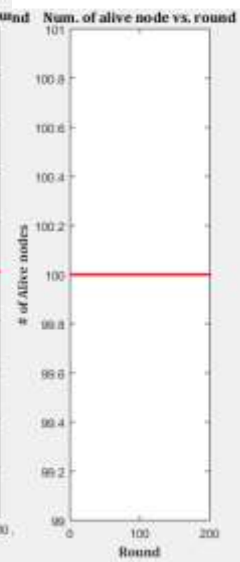
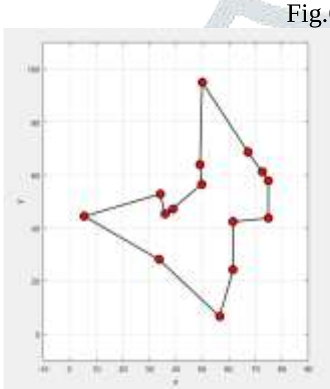


Fig.6 No. of Dead nodes Fig.7 No. of Alive nodes



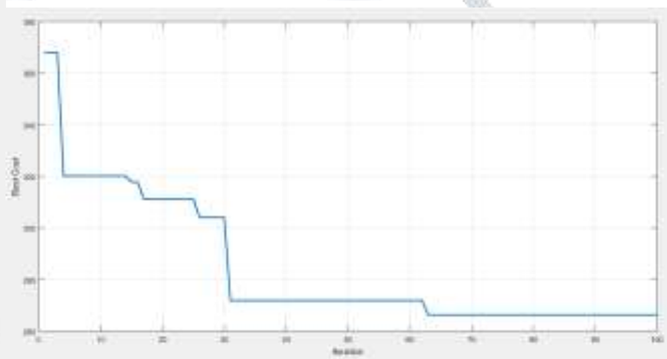
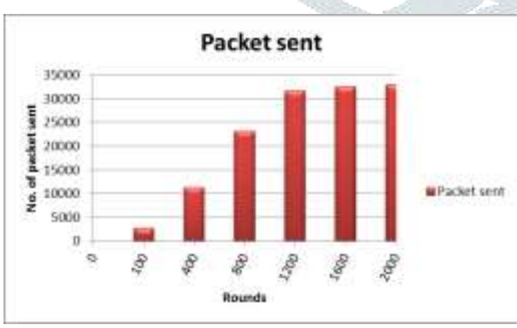


Fig.8 Optimal path among CHs Fig.9 Best cost vs Iteration

It is observed that number of packet sent increases, total energy of nodes decreases, number of CH selected depends on probability and energy level of nodes, number of dead nodes are 0 and number of alive nodes are 100 and best cost of optimal path decreases with increase in number of iteration. Now the same simulation set up is implemented with variation in number of rounds from 100 rounds to 2000 rounds. Increase in number of rounds results in increase in number of packet sent as shown in Fig. 10. Similarly, number of dead nodes increases with increase in number of rounds. On the other hand total energy of the network depletes with increase in the number of rounds, number of CH selected depends upon the energy level of the nodes and probability, number of alive nodes decreases with increase in number of rounds and the best cost value depends on the number of CH selected and the distance between the selected CHs and BS as shown in Fig. 11-14.



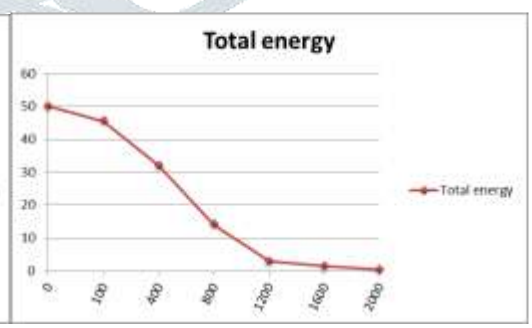


Fig.10 No. of Packet sent to BS Fig.11 Total energy

With increase in number of rounds the energy of nodes get depleted because the energy is utilized for transmitting the data towards the BS. This results in decrease in total energy of the network, increase in number of dead nodes and decrease in number of alive nodes. Number of data packet sent delivered to BS shows the amount of information passing through the network and it increases with the increase in number of rounds.

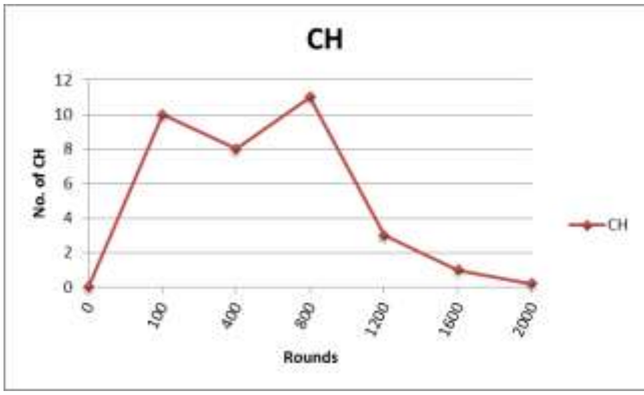


Fig.12 CH selected per round

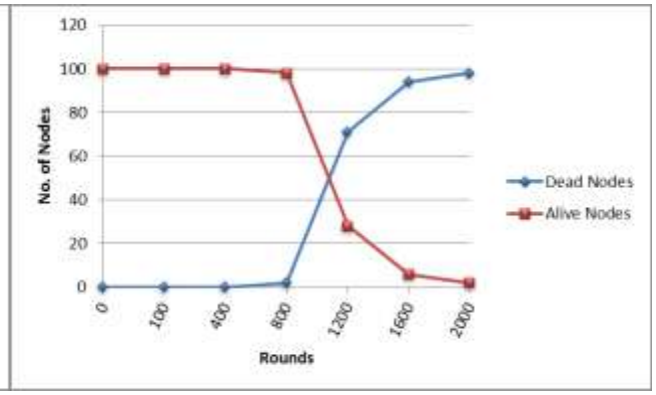


Fig.13 No. of Dead and Alive nodes

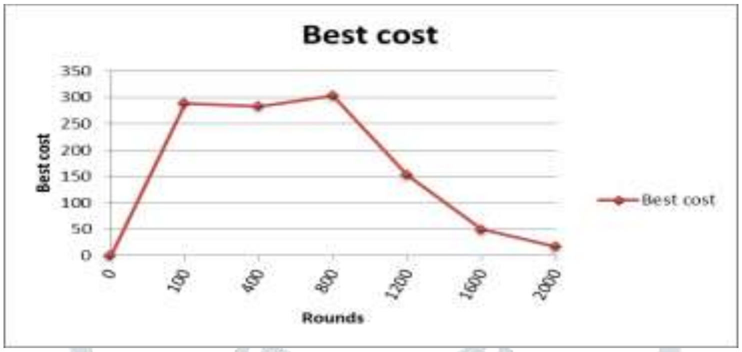


Fig.14 Best cost

For reliability of results, same simulation set up has been used for variation in number of nodes as 200 and 300. Simulation results are summarized in Table2 and Table3.

Table2. Performance evaluation with 200 Nodes

No. of rounds	Packet sent	Total energy	CH	Dead nodes	Alive Nodes	Best cost
100	5800	90.2	20	0	200	411.0636
400	22950	61.55	20	0	200	393.3522
800	46000	22.8	21	10	190	409.8306
1200	59400	2.7	3.3	164	36	154.7359
1600	61600	0.76	0.5	197	3	25.2992
2000	61900	0.435	0	198	2	0

Table3. Performance evaluation with 300 Nodes

No. of rounds	Packet sent	Total energy	CH	Dead nodes	Alive Nodes	Best cost
100	8701	134.52	29	0	300	495.0496
400	35030	87.7	32	0	300	498.4968
800	65975	28	27	32	268	452.1237
1200	85700	5	3	274	26	159.6618
1600	85800	0.99	0.2	298	2	14.12365
2000	86000	0.75	0	299	1	0

From Table1 and Table2 it is concluded that with the increase in number of nodes and number of rounds the number of packet sent also increases. With the increase in number of nodes the total energy of the network can be maintained for longer time. Selection of number of channel head depends on the energy of the sensor nodes. Number of dead nodes increases with increase in number of rounds and number of alive node decreases with increase in number of rounds. Best cost depends on number of selected CHs and the distance between the CHS and base station.

ii. With varying position of Base Station

In real time scenario position of nodes and BS may vary. So, in this section performance of RLEACH-ACO has been evaluated for varying the position of nodes as well as BS dynamically. Sensor field with Dynamic BS and 200 sensor nodes is shown in fig. 15. The simulation set up as explained in section 4 is considered for 200 nodes. Simulation is carried out for same parameters and network.

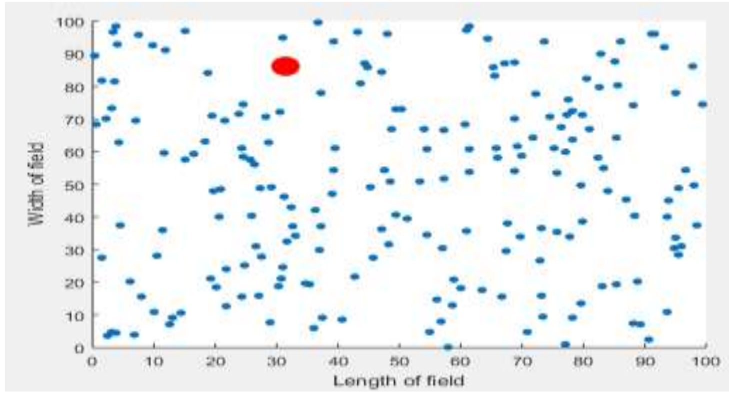


Fig.15 Deployment of 200 nodes with Dynamic BS

Fig.16-22 shows number of packets sent, total energy, number of CH selected, number of dead nodes and alive nodes, optimal path among selected CH and best cost for 200 sensor nodes and 200 rounds.

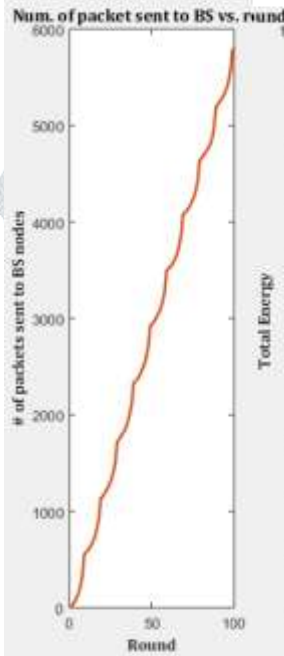


Fig.16 No. of packet sent

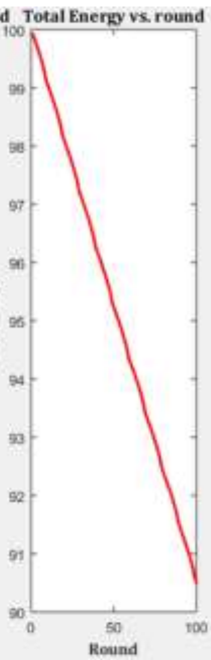


Fig.17 Total energy

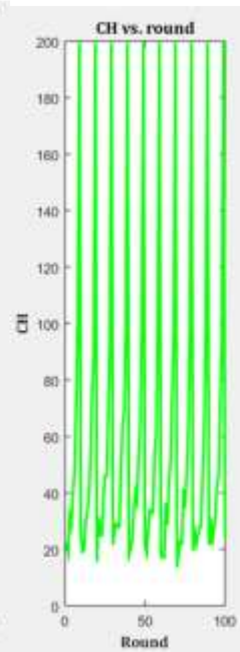


Fig.18 CH selected

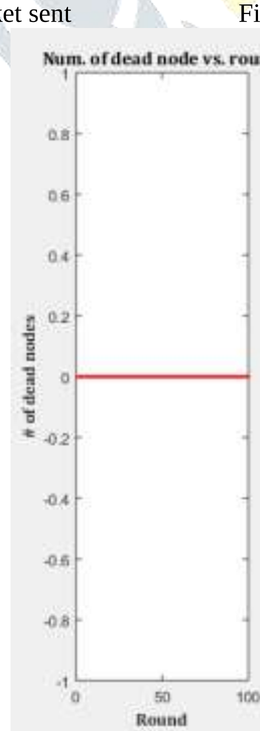


Fig.19 No. of Dead nodes

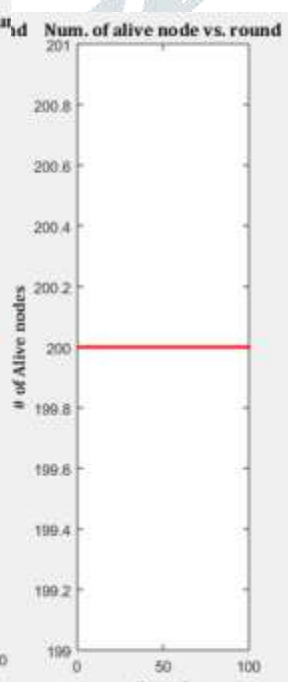


Fig.20 No. of Alive nodes

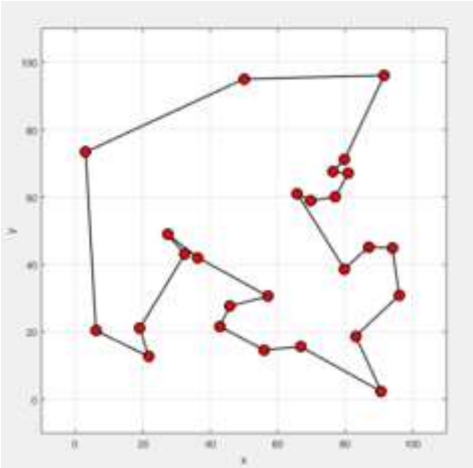


Fig.21 Optimal path among CHs

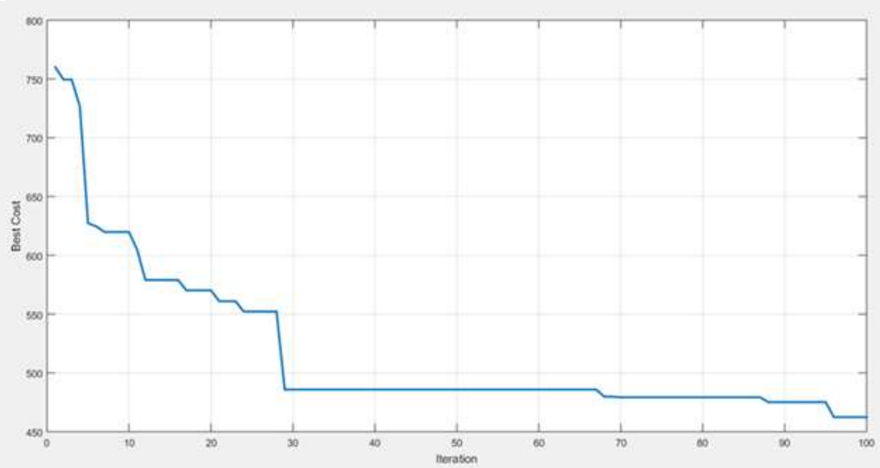


Fig.22 Best Cost

Simulation results of sensor field for various rounds with 200 nodes and dynamic base station are summarized in Table 4. It is observed that the sensor field is stable for longer period of time and ACO estimates the best route among CHs. These parameter together makes entire WSNs energy efficient and enhances the lifetime of WSN.

Table4. Performance evaluation with 200 Nodes with Dynamic BS

No. of rounds	Packet sent	Total energy	CH	Dead nodes	Alive Nodes	Best cost
100	5800	90.77	24	0	200	448.291
400	23175	62.08	19	0	200	403.5754
800	46435	26.45	18	4	196	387.818
1200	62700	2.55	5	149	51	243.3107
1600	62875	0.69	0.7	195	5	90.7318
2000	63000	0.49	0	199	1	0

VI. CONCLUSIONS

Energy efficiency is the main factor in designing WSNs. For clustering LEACH is used and ACO is used for estimating the optimal path among selected CHs. RLEACH-ACO has been proposed and evaluated by varying number of nodes, number of rounds and by varying the position of BS. It is concluded that with the increase in number of rounds the energy of nodes get depleted because the energy is utilized for transmitting the data towards the BS. When total energy of the network is compared in terms of number of nodes, it is concluded that with the increase in number of nodes from 100 to 300 the total energy of the network can be maintained stable for longer time. Finally, the simulation result shows superiority of proposed method in terms of number of packet sent to BS, total energy, number of dead nodes and alive nodes left and best cost of the optimal path as compared to existing techniques [13].

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