Fuzzy Logic Based Energy Efficient Clustering in Wireless Sensor Networks

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***Abstract*— During the network formation, all nodes will have the same amount of residual energy. As the nodes start participating in the routing process, they tend to lose the energy levels and a point is reached in which they eventually become dead after repeated participations which degrade the lifetime ratio of the network. The Base Station (BS) will become mobile and hence can reach nodes so that overall energy consumption by nodes is reduced. In this paper, LEACH algorithm is modified by selecting the Cluster head based on Fuzzy Logic and genetic algorithm executing sequence of operations namely chromosomes, crossover, and mutation is applied in order to recover the dead nodes in the network. The proposed genetic and fuzzy logic algorithms outperform LEACH with respect to many parameters like Number of Alive nodes, Number of Dead Nodes, Lifetime Ratio and Residual Energy by using MATLAB.

***Keywords*— Cluster Head, Fuzzy Logic, Chromosomes, Crossover, Mutation.**

I. INTRODUCTION

The Wireless Sensor Networks (WSN) is a demanding field which has varying benefits in the area of industrial as well as socio-economic fields. The sink gather the data from the sensor nodes and also delivers the data to sensor nodes depending upon the use case [1].The energy consumption is high for such use cases. Energy consumption formula has a direct relation with respect to transmission energy and the distance between the nodes in the network. The more closer the two nodes less is the energy consumption.

In a Hierarchical Network, the nodes are spread across multiple areas and each of the area will have a set of nodes. One among the nodes is selected as the leader node (LN) which communicates between two different areas. The overall energy consumption can be reduced and lifetime ratio can be increased if the LN is selected in an optimized fashion. One more use case comes if we have a mobile sink nodes then the energy consumption can be reduced by communicating with respect to nodes at a closer distance which also improves lifetime ratio.

LEACH [2] is a platform specific protocol to select the LN randomly in each round. The LEACH is enhanced with the help of CHEF method [3] to select a better LN. In CHEF method the LN is selected by calculating both residual energy and distance with respect to BS.

The hierarchical network is represented in the fig1. As shown in the fig, there are four areas which are bounded in the area of 100*100 m. The first area has 5 nodes, second area has 10 nodes, third area has 8 nodes and fourth area has 15 nodes.

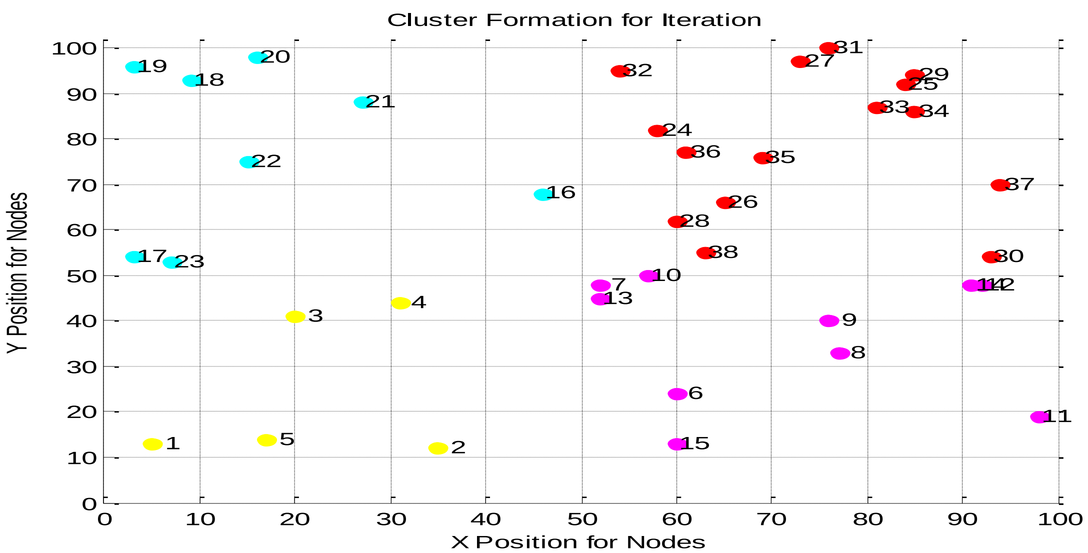

Fig. 1. Hierarchical Network Formation

Node1 to Node 5 occupy the area1, Node 6 to Node 15 occupy the area2, Node 16 to Node 24 are in area3 and finally remaining nodes are in the area4. Each area nodes also are bounded by respective area limits. Area1 nodes are within (1,50) x and (1,50) y. Area 2 nodes are within (51,100) x and (1,50) y. Area 3 nodes are within (1,50) x and (51,100)y. Area 4 nodes are within (51,100) x and (51,100)y.

Data Collection process helps in reduction of energy consumption. For improvement of lifetime ratio few approaches makes use of awake- sleep dual policy approach. Few papers in the literature also address relocation of sink node and few address periodic exchange of data packets between nodes so that load is reduced.

In this paper will perform the sanity check of the nodes and then it will check the nodes energy level in order to select the best LN. Path will be establish from source node to leader node and leader node to destination node and then use Genetic algorithm to recover the dead nodes which can maintain the network lifetime.

II. BACKGROUND

Fuzzy based method [5] makes use of local LN selection. By making use of fuzzy logic there is reduction in cost computation and then lifetime ratio is also increased. The nodes in the area communicate with each other and then decide which node to act as a LN.

Nguyen et al found out a method in which LEACH [6] was modified in order to improve the life expectancy..

Wang et al [7] proposed that, the relay stations can be placed at random locations which can result in energy balance and lifetime improvement.

The target is a node which moves in a certain direction. The detection of target path can be done in a energy aware approach with the help of protocol, proposed by Yu-Chen and his co-authors [8]. When t he path is broken by the movement of target, nodes can repair the path effectively.

The residual energy of the nodes in a given area are added and then divided by the number of nodes in an area so that an appropriate base station is selected and mobile station (MS) can be used to transmit data. This helps in improving energy efficiency as described by authors Xun-Xin, Yuan, and Zhang Rui-Hua in [9].

Each sensor is assigned a specific job. Set up phase and data forward phase are used in routing process by making use of hierarchy-based routing [10].

When a node wants to communicate to a node residing in a different area then it can be single hop and multi hop. data packets are transmitted between base station and nodes and vice versa. There is a comparison between hop based approaches with routing process [11].

The performance of energy efficiency based routing has better performance with respect to time and energy levels as compared to conventional routing. The prediction strategy will determine the location of the destination node and then forwards the data traffic towards it [12].

Mobile assisted method with the help of sink node is used to send routing packets to be send towards receiver [13]. The method will reduce the links between the initiator and receiver which in turn reduces time taken and also performs the increase in the lifetime.

Mobile Sink Assisted Energy Efficient Routing Algorithm (MSA) [14] has improved lifetime because the data is collected by sink node and hence the normal nodes will have little amount of energy reduction during routing process.

Active and passive methods of energy control are presented. Amount of energy needed to send data, energy required for management of data is also presented [15]

Mobile sink based Energy-efficient Clustering Algorithm (MECA) [16] divides the area into sub-areas. In each area a node will be selected which will act like a LN by using the residual energy values of nodes. The nodes which are not LN will send data packet to LN and then LN will send it to sink.

III. NODE LOCATION MECHANISM

The node (RE, MH, SD) is defined as an entity which will have Remaining Energy (RE), Memory Handler (MH) and Sensing Device (SD). Several such (RE, MH, SD) form a network. The area is bounded by the limits (xsi,xei) and (ysi,yei). If xsi is the starting x position for the area and xei is the ending x position for the area. ysi is the starting y position for the area and yei is the ending y position for the area. Two nodes cannot have the same position at any given point of time. Fig 2 shows the node location strategy used in simulation

Algorithm1: Node **Location** Strategy for simulation

Input: $N_{nodes}, x_{si}, x_{ei}, y_{si}, y_{ei}$

Output: Node Location Matrix (NLI)

Detail Steps:

a) $l = 1$

b) $l : 1 --> N_{nodes}$

c) Generate a x value of node which satisfies the objective function

$x_l = val,\ any\ val\ which\ satifies$

$x_{si} \le val \le x_{ei}\ \ \&\ val \ne x_{hi}$

d) Generate a y value of node satisfies the objective function

$y_l = val\ \ \ any\ val\ which\ satifies$

$y_{si} \le val \le y_{ei}\ \ \&v \ne y_{hi}$

Where,

$x_{hi} - history\ of\ \ x\ \ positions\ \ previously\ assigned$

$y_{hi} - history\ of\ \ y\ \ positions\ \ previously assigned$

e) Form a tuple in the format $(l,(x_l, y_l))$

f) Store in the l^{th} row of Matrix

Node	Position
l	(x_l, y_l)

g) $l = l + 1$

Fig. 2. Node Location Strategy for Simulation

Node Deployment area is responsible for spreading the nodes across multiple areas in the network. For each of the area independently node location strategy is executed and the nodes are placed in that area.

IV. BATTERY UPDATION

Suppose the routing path ***is sn-->in1--->in2-->dn***, where sn is the source node, in1 and in2 are the intermediate nodes and dn is the destination node. The energy consumed between nodes ***source node*** **-->** ***intermediate node*** by using a distance of 30m. can be computed using equation (1)

$$Ec = 2 * Etx + Egen\ \ * d\ \ \wedge delta \qquad (1)$$

Etx = Energy required for transmission
Egen = Energy required for generation
d = distance between the nodes
delta = attenuation factor

we will get a value of 2* 50 + 100 * 30^0.5 and that will be 0.0055 . Few standards for energy transmission and reception is given in Table1 as mentioned in [17]

Table 1: Energy Computation Values

Parameter Name	Energy Consumption
Energy required for transmission	50 mJ/bit
Energy required for generation	100 mJ bit/m

The updating of energy levels are computed by reducing the energy consumed value over the link as defined by equation2

$$UEn = CEn - Ec \quad (2)$$

UEn = Updated Energy
CEn = Consumed Energy
Ec = Energy Consumed

Whenever the nodes participate in the routing path they lose their energy and then if the nodes are used in the routing path regularly over a certain time period the nodes lose the energy levels in a drastic mode and become dead nodes. If BI is the battery initial value then set of nodes whose energy levels become less than BI/4 becomes dead nodes.

V.PROPOSED METHOD

The proposed method can be divided into multiple slices namely Leader Node Election based on the Fuzzy Method, Route Path Find process, Genetic process to recover dead nodes.

A. Fuzzy Based Leader Node Election

The nodes in an area discuss among themselves selection of Leader Node by performing distance categorization and energy categorization. The selection of Leader Node is represented as shown in Fig3.

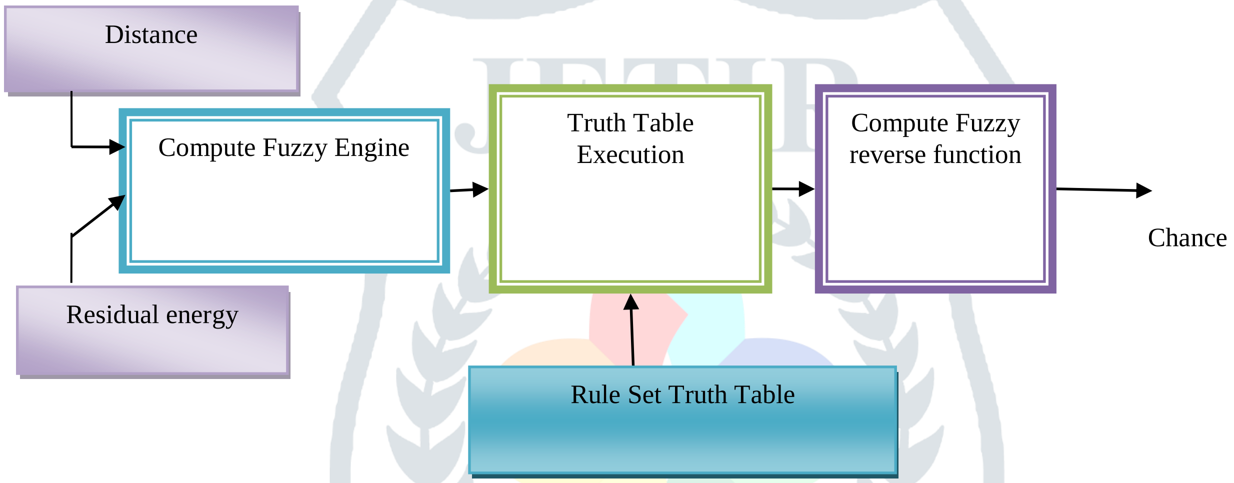

Fig 3. Fuzzy Based Leader Node Election

Fig 3 shows the CHEF cluster head election. As shown in the fig Distance and Residual Energy will act like an input. The compute fuzzy engine assigns 3 variables for distance which can be NEAR, FAR and MEDIUM and Residual Energy values will be computed and each node will be assigned a variable LOW, MEDIUM and HIGH. The Trust table defined in Table 2 will be used for leader node execution and the fuzzy reverse function is computed to obtain the chance variable. Very.LARGE will have better chance to become leader node followed by LARGE followed by Small.LARGE.

Table 2: Truth Table For Leader Node

Residual Energy	Local Distance	Chance
LOW	FAR	Very. SMALL
LOW	MEDIUM	Little. SMALL
LOW	NEAR	SMALL
MEDIUM	FAR	Small. MEDIUM
MEDIUM	MEDIUM	MEDIUM
MEDIUM	NEAR	Very. MEDIUM
HIGH	FAR	Small. LARGE

HIGH	MEDIUM	LARGE
HIGH	NEAR	Very. LARGE

B.CHEF Route Discovery

CHEF route discovery make use of leader node and normal nodes to form the complete routing path.

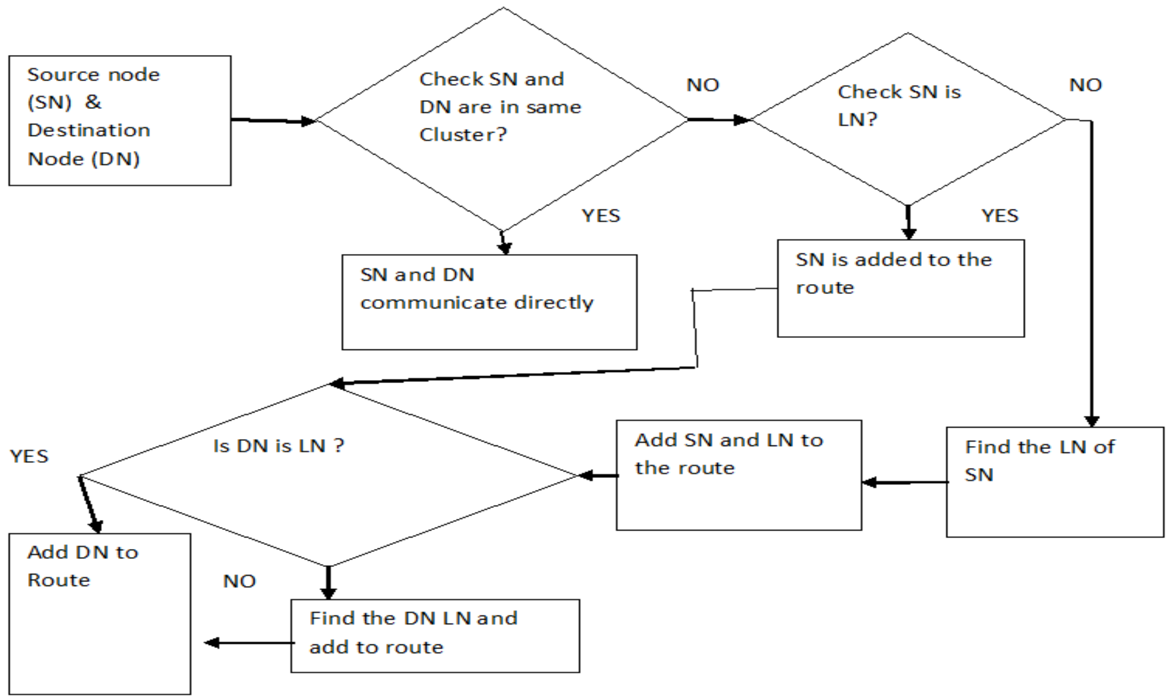

Fig. 4. CHEF Route Discovery

Fig 4 shows the CHEF Route Discovery. As shown in the Fig 4 1. SN and DN will act like an input, Find whether SN and DN belongs to the same cluster if yes communicate directly otherwise proceed to select LN of SN. Add SN LN to route. SNLN will send the RREQ to leader nodes of the remaining clusters leaving initiator cluster and then obtains REPLY from destination node leader node (DNLN). SNLN will communicate DNLN. If DNLN is the DN then stop otherwise DNLN communicates to DN. SN is source node, DN is destination node, SNLN is the source node leader node and DNLN destination node leader node.

C. Node Recovery using Genetic Detection

Genetic Algorithm must run for node recovery and it has to run after every N data transmissions. Check the total number faulty nodes in the network (energy less than the threshold value).If the numbers of fault nodes greater than 1 then recovery process are processed. The Node recovery process is defined in Fig 5

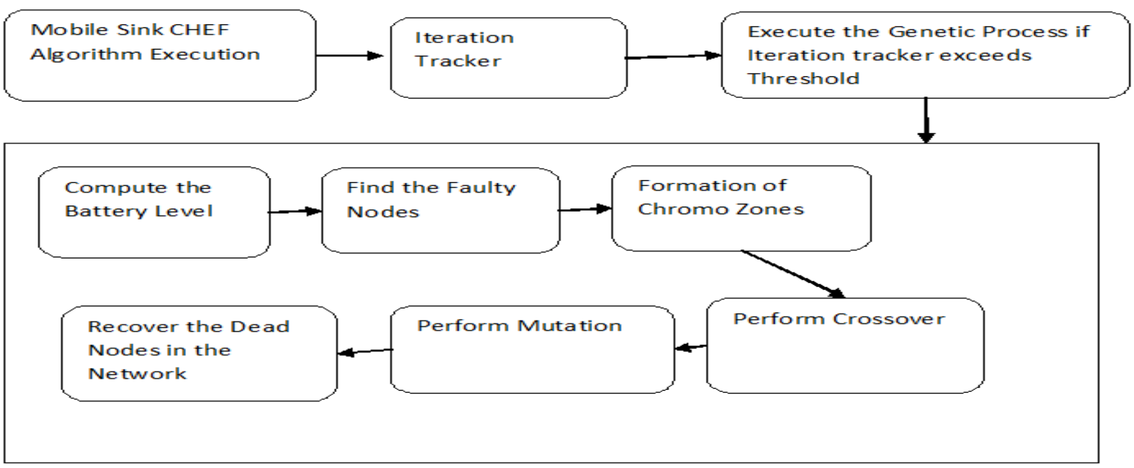

Fig 5. Node Recovery Process

The Mobile Sink CHEF is executed to collect the data from the nodes. The number of cycles the data collection happens is tracked. Once the iteration tracker number exceeds the threshold the genetic process will get triggered. Compute the Faulty Nodes in the network by computing the battery level of the nodes in the network. If the remaining energy of the nodes is lesser than threshold battery level then add the node to faulty nodes. The chromo zones are formed by making use of genetic which is representation in binary manner into four different matrices. The Crossover module is responsible for dividing the chromo zones into half of the matrix and then exchanges the bits. The Mutation is responsible for randomly picking one of the bits of the gene and then replacing the 0 with 1 and Find the position of the 1s and identify the dead nodes which have to be recovered

VI. SIMULATION RESULTS

The Simulation results are presented here for GENETIC, CHEF and LEACH. Table 3 shows the simulation set up

TABLE 3. SIMULATION SET UP

Parameter Name	Parameter Value
Transmission Energy	20 mJ
Generation Energy	10 mJ
Attenuation Factor	0.7
Number of Iterations	100
Initial Battery Energy	200 mJ
Number of Areas	4
Number of Nodes in Area1	5
Number of Nodes in Area2	5
Number of Nodes in Area3	5
Number of Nodes in Area4	5
Base Station ID	20

TABLE 3. Shows the given Input. Energy required for Transmission and Generation is 20 and 10 MegaJoule (mJ) , transmission energy always greater than generation energy. Attenuation Factor is also called delta is value varys from 0.1 to 1.0. Initial Battery Energy is for all the nodes as 200 MegaJoule. Number of area is to deploy the nodes and all the 4 area consist of 5 nodes. Base station Id is 20.

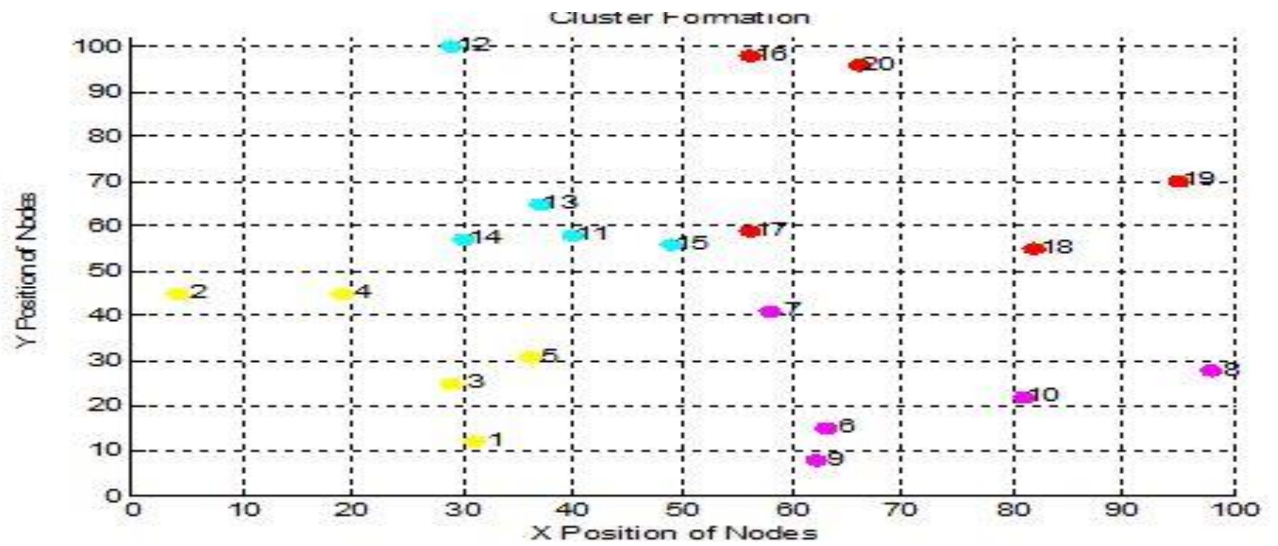

Fig. 6. Nodes Deployment Area

Fig6. Shows the nodes deployment area . Area 1 has 5 nodes which are {Node1, Node2, Node3,Node4,Node5}, Area 2 has 5 nodes which are placed between 51 to 100 on the x and 1 to 50 on the y which are {Node6, Node7,Node8,Node9,Node 10}, Area 3 will have 5 nodes which are placed in the range of 1 to 50 on x and 51 and 100 on the y which are {Node11, Node12, Node13, Node14,Node 15}. Area 4 has 5 nodes which are place between 51 to 100 on x and 51 to 100 on y which are {Node16, Node17, Node18, Node19,Node20}.

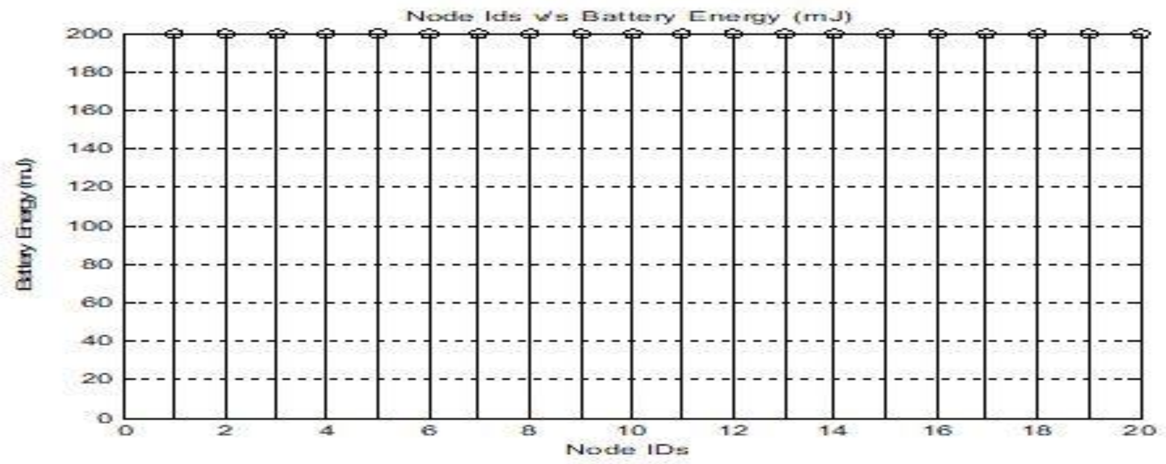

Fig7. Battery Initialization of Nodes

Fig 7. Shows the battery initialization will be having the same amount of battery level during the network initialization.

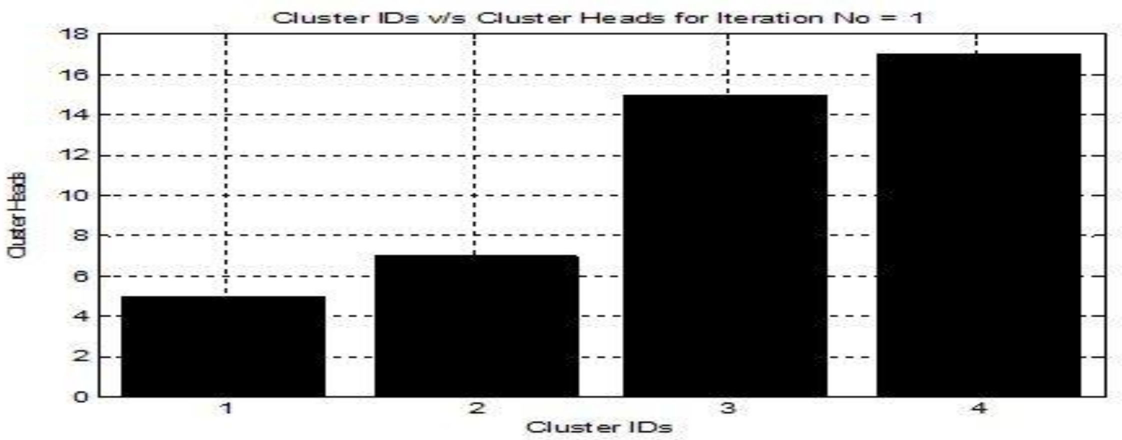

Fig. 8. Leader Node Election

Fig 8 shows the Leader Node Election. As shown in the fig For Area1 has the leader node 5. Area 2 has the leader node 7, Area 3 has the leader node 15 and Area 4 has the leader node 17.

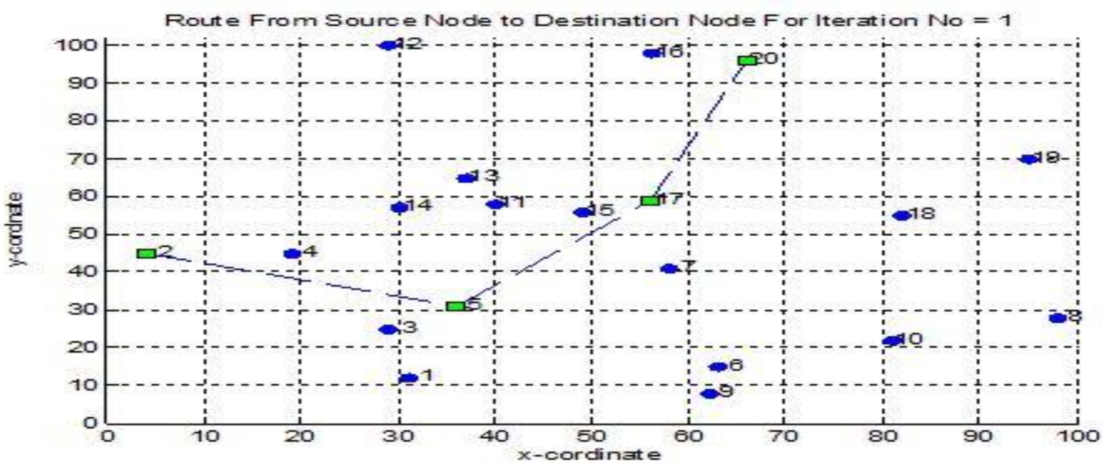

Fig. 9. Route Discovery End to End

The end to end route discovery process is shown in the fig 9. As shown in the fig Node2 is the source node and Node 20 is the destination node. The routing path is 2-→ 5→ 7→ 20. Node 5 is the leader node for area1 and Node 7 is the leader node for area4. The above process is executed for 10 iterations.

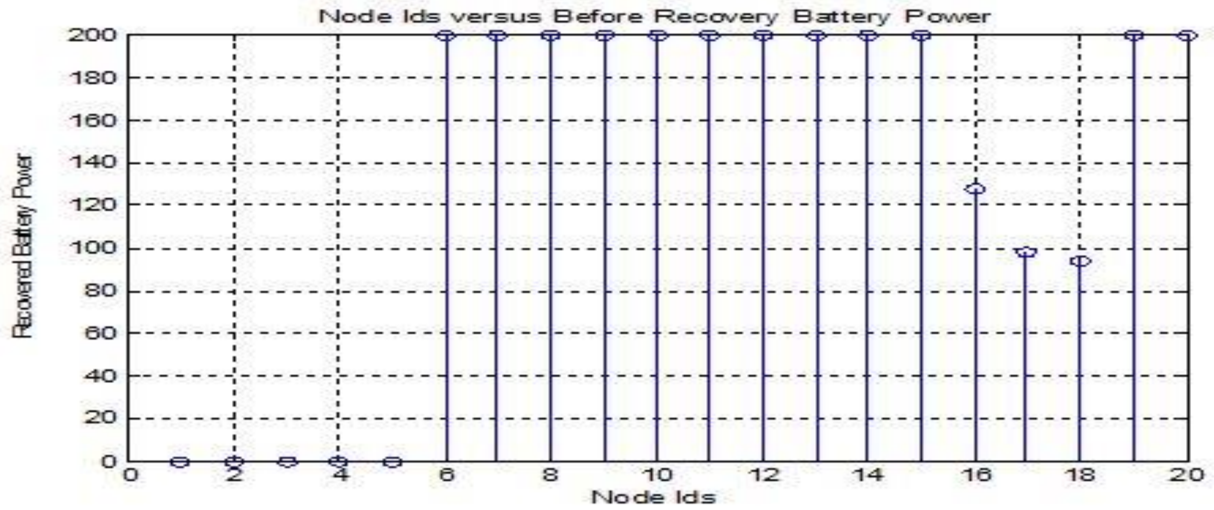

Fig . 10. Levels of Battery before Genetic Execution

Fig 10 shows the battery levels for the nodes before the genetic process is triggered. From the Fig 9 it is evident that Node1, Node2, Node3, Node4, Node5 have lost their enegy levels completely. Node 16, Node 17 and Node 18 have lost the energy levels with little amount because of lesser participation in routing and remaning nodes have there energy levels highest as they are not used in any routing path.

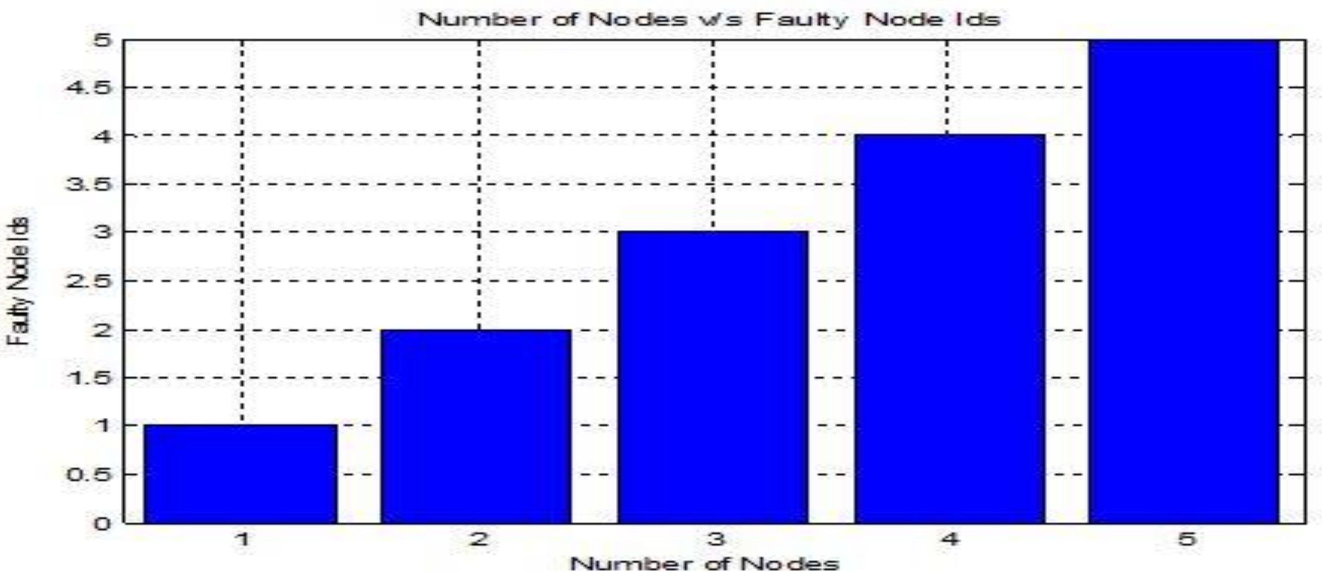

Fig. 11. Dead Nodes across four clusters of Nodes

Fig 11. Shows that there are five faulty nodes. As shown in the Fig the 1st dead node is Node1, the 2nd dead node is Node2, 3rd dead node Node3, 4th dead Node is 4 and 5th dead Node is 5. If the initial energy is 200 then set of nodes whose remaning energy is less than 50 becomes dead node.

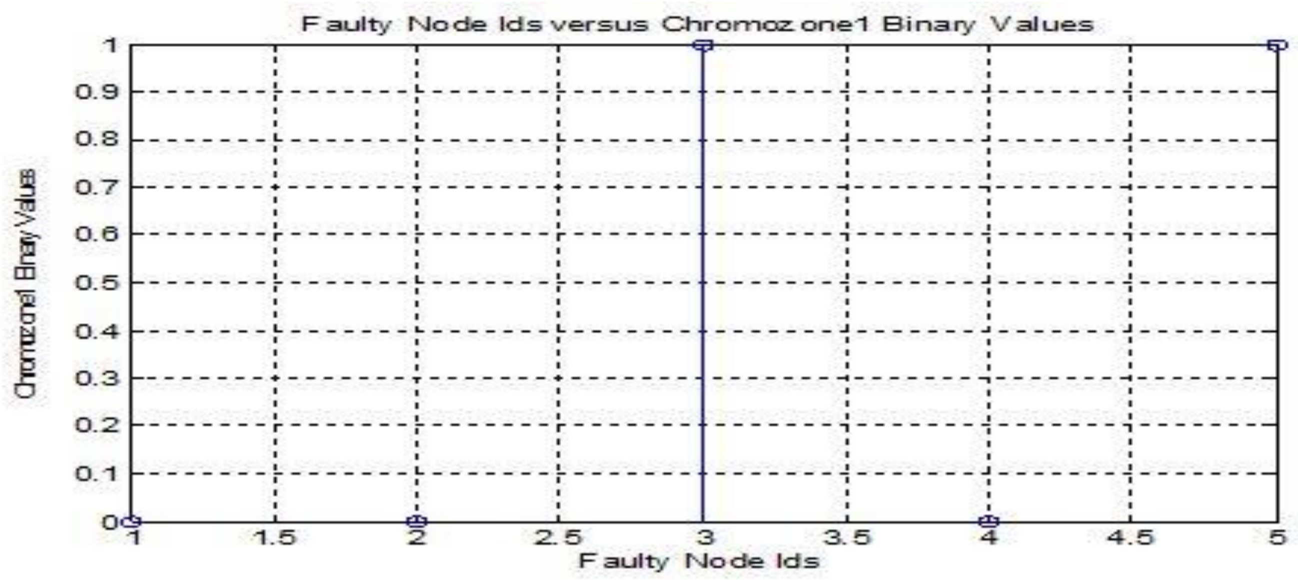

Fig. 12. Chromosome1 Formation of Nodes

Fig 12. Shows the Chromosome1 Formation of Nodes in which therir are five faulty nodes and the first chromosome is {0.0,1.0,1}.

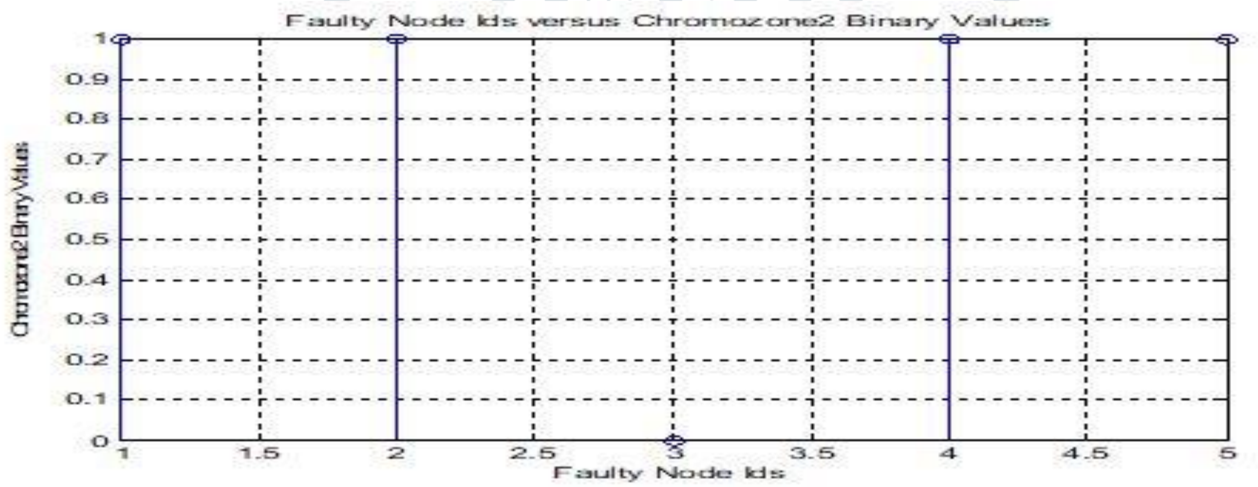

Fig. 13. Chromosome2 Formation of Nodes

Fig 13. Shows the Chromosome2 Formation of Nodes in which there are 5 faulty nodes and the second chromosome is {1.1,0.1,1}.

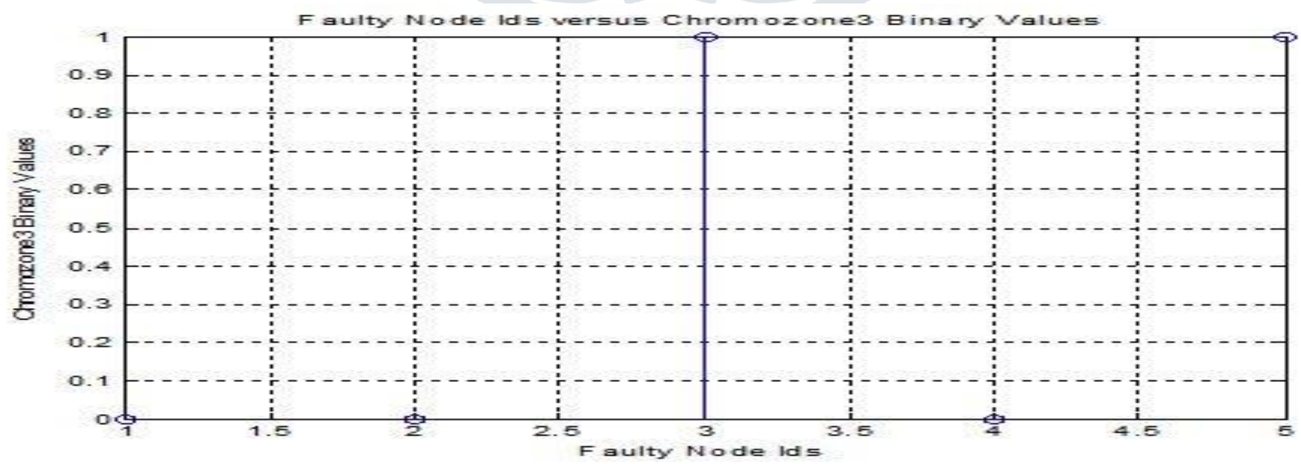

Fig. 14. Chromosome3 Formation of Nodes

Fig 14. Shows the Chromosome3 Formation in which there are 5 faulty nodes are there and the third chromosome is {0.0,1.0,0}.

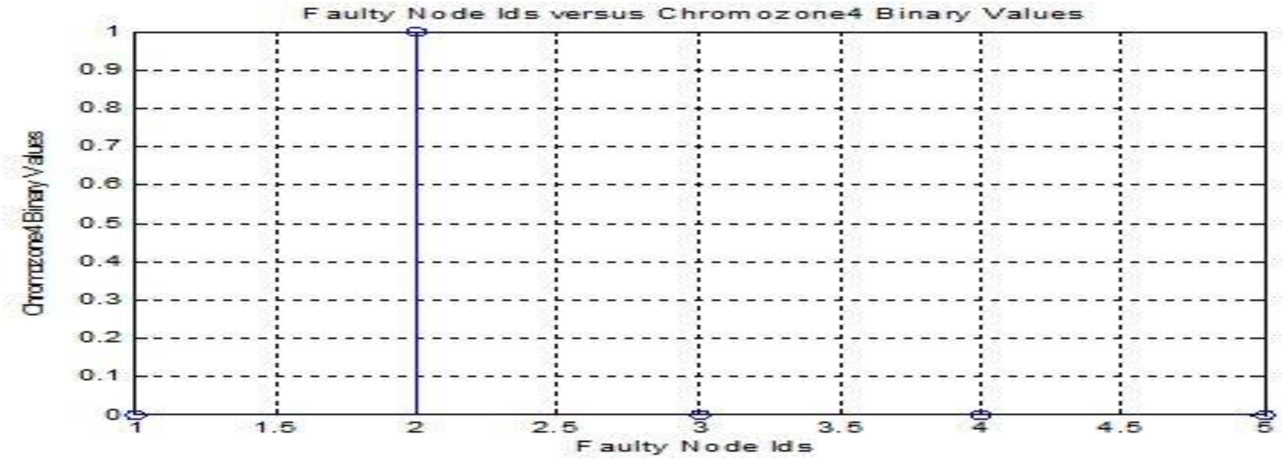

Fig. 15. Chromosome4Formation of Nodes

Fig 15. Shows the Chromosome4 Formation in which there are 5 faulty nodes and the fourth chromosome is {0.1,0.0,0}.

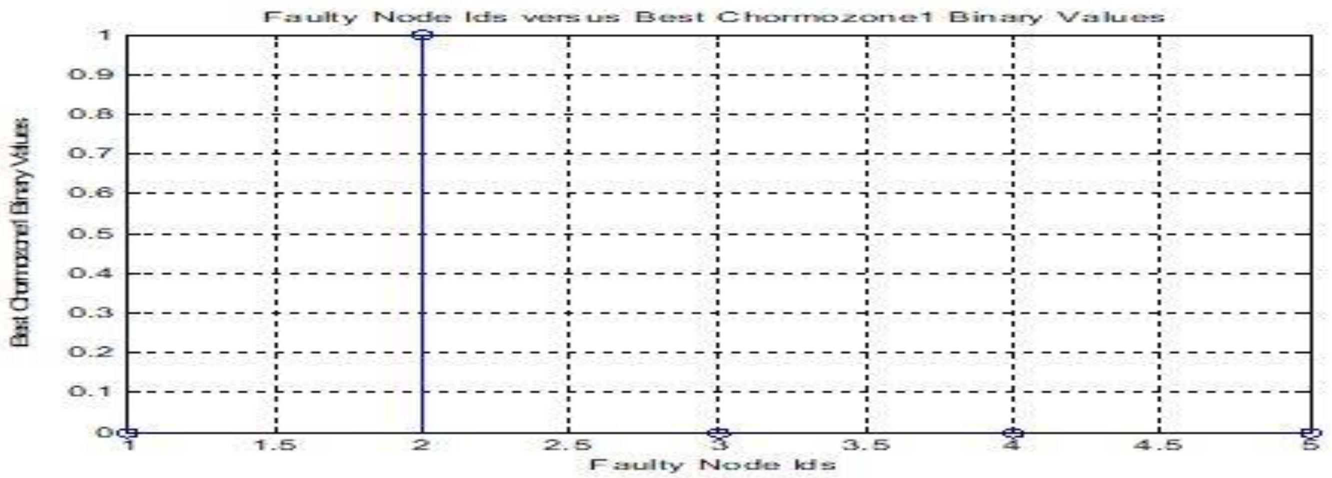

Fig. 16. Best Chromosome1 Formation of Nodes

Fig 16. Shows the best chromosome1 formation of nodes which maximum number of zeros and it is {0,1,0,0,0}

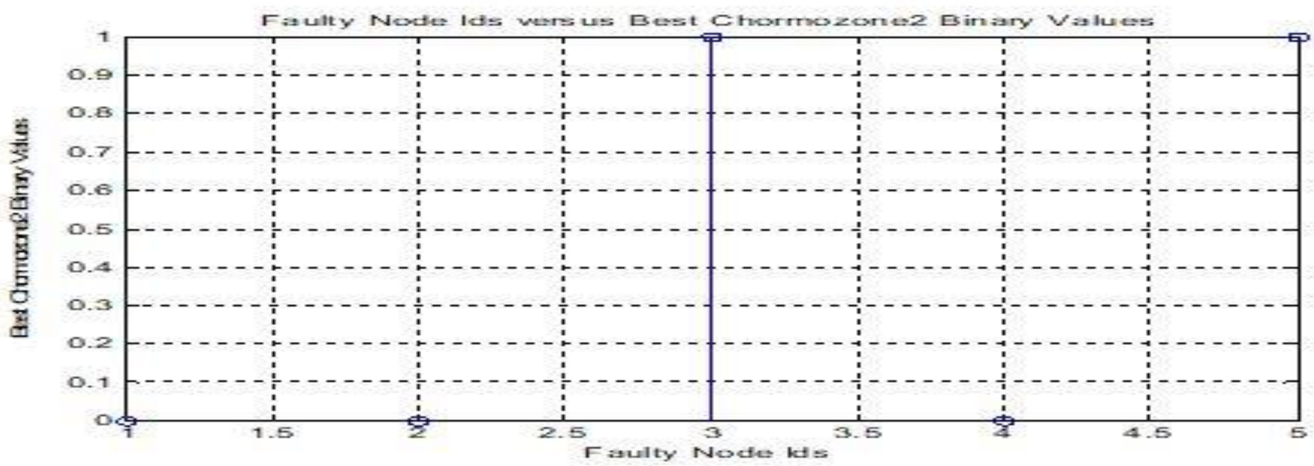

Fig. 17. Best Chromosome2 Formation of Nodes

Fig 17. Shows the best chromosome2 formation of nodes which has maximum number of zeros and it is {0,0,1,0,1}

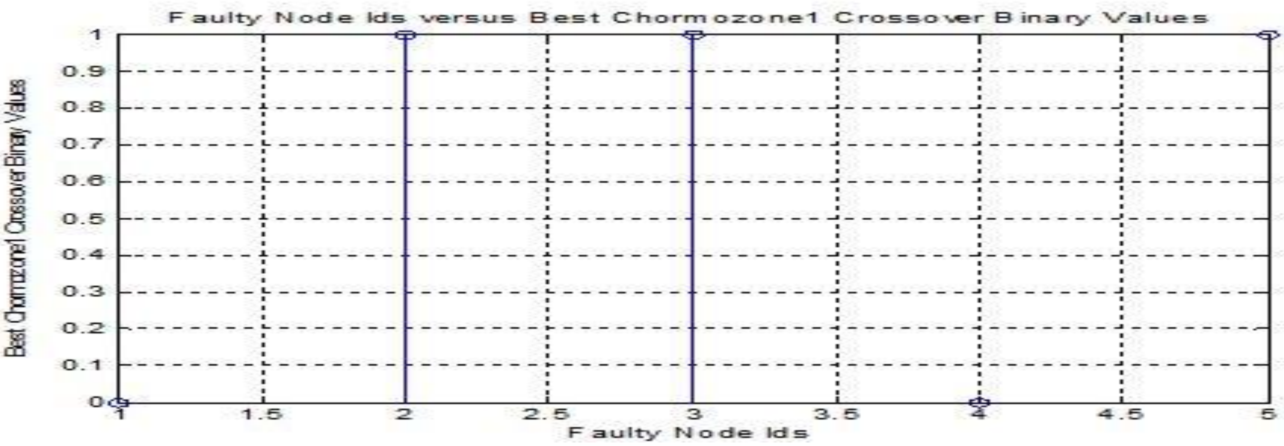

Fig. 18. Crossover 1 Formation of Nodes

Fig 18. shows the crossover 1 formation of nodes for the best chromosomes which is {0,1,1,0,1}

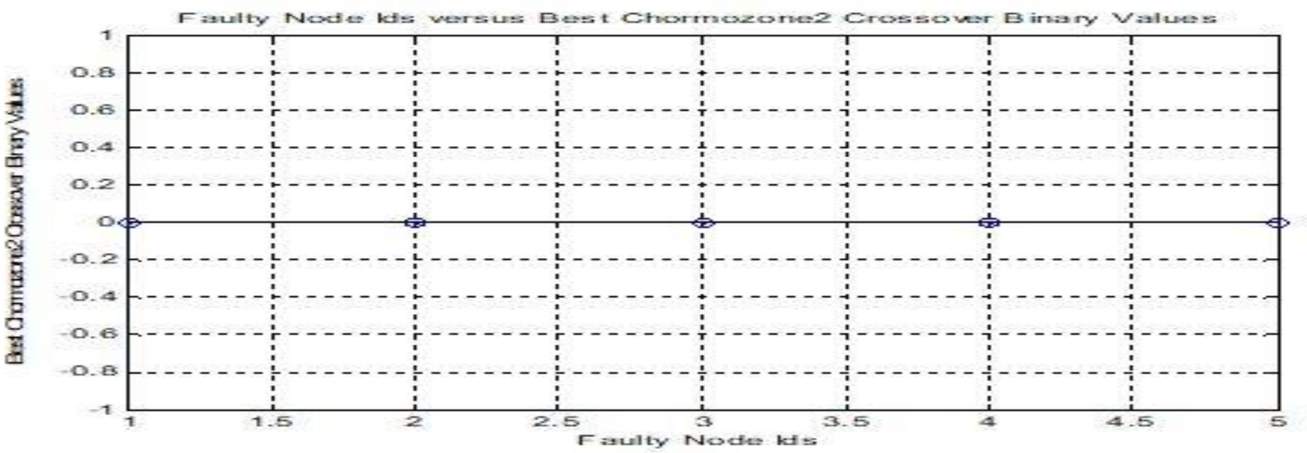

Fig. 19. Crossover 2 Formation of Nodes

Fig 19. shows the Crossover2 formation of nodes in which the best chromosomes bits were exchanged to form {0,0,0,0,0}

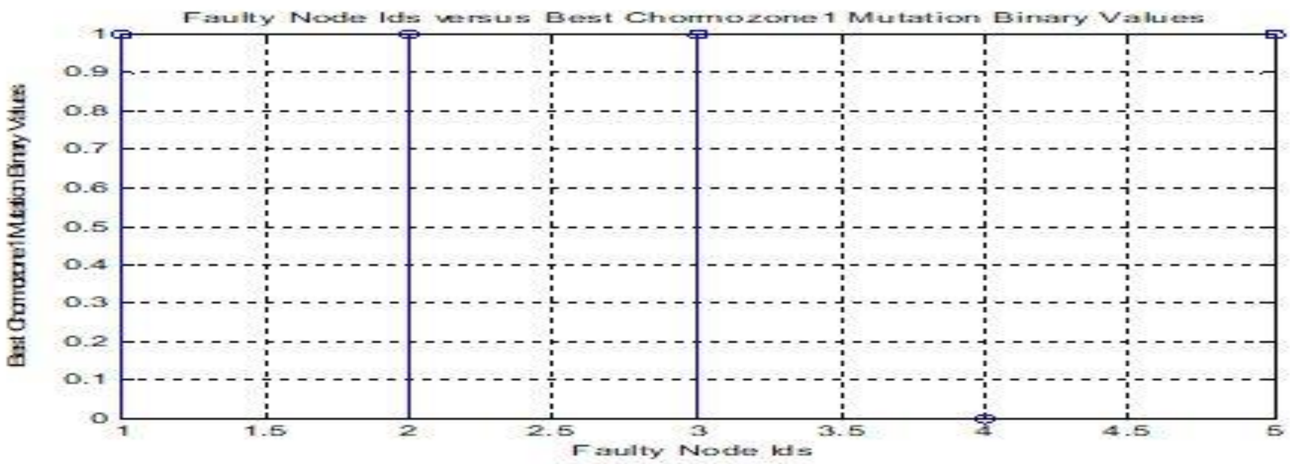

Fig. 20. Mutation1 Formation of Nodes

Fig 20. shows the muatation 1 formation of nodes in which one of the bit of crossover value {0,1,1,0,1} is changed from 0 to 1 is {1,1,1,0,1} . In this case the first bit has been changed from 0 to1.

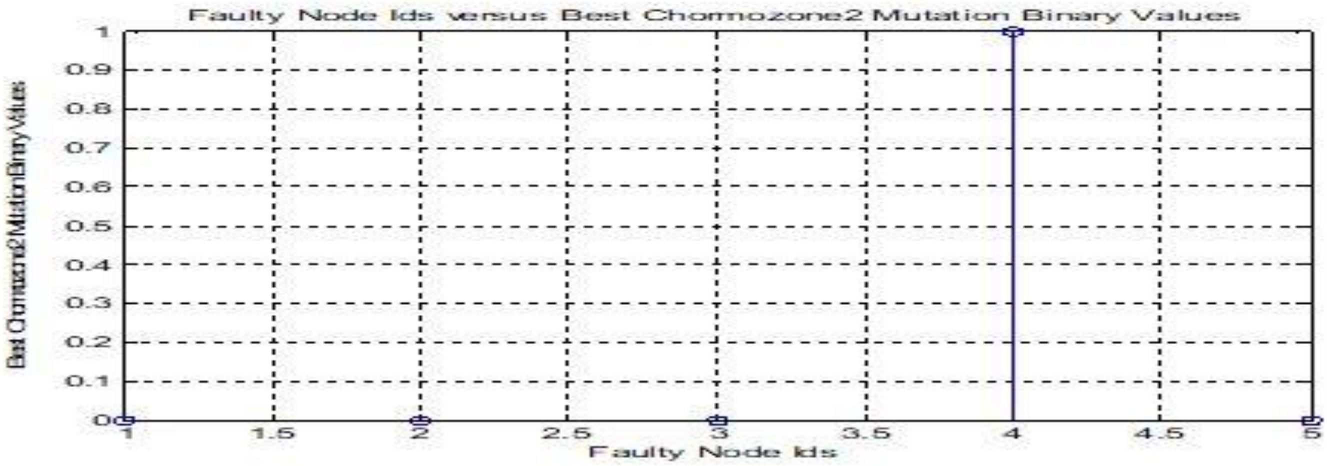

Fig. 21. Mutation2 Formation of Nodes

Fig 21. shows the mutation 2 formation of nodes in which one of the bit of crossover value {0,0,0,0,0} is changed from 0 to 1 is {0,0,0,1,0} . In this case, the fourth bit has been changed from 0 to1.

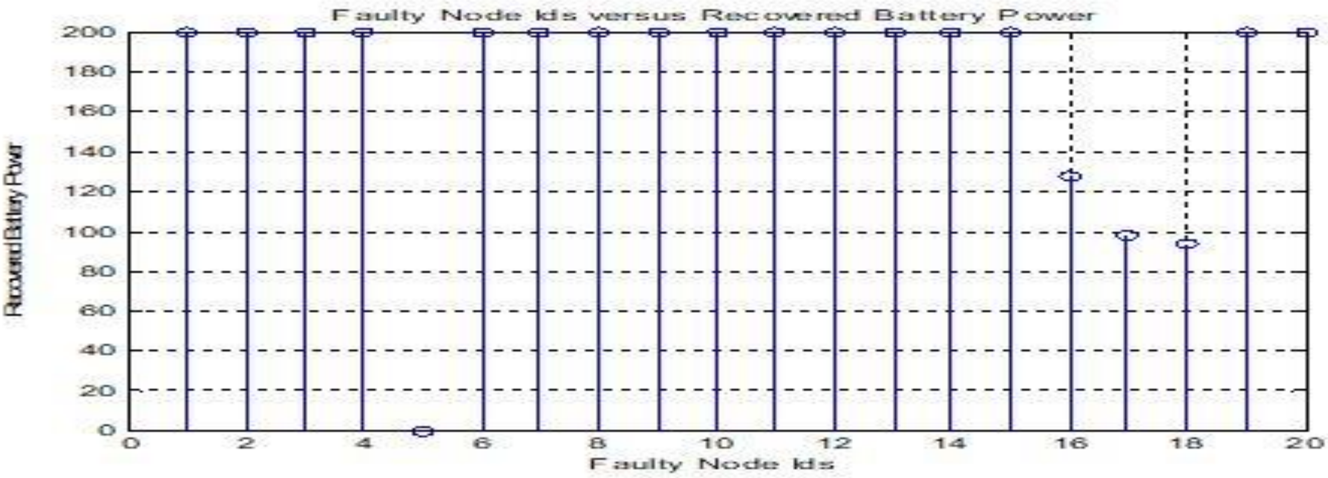

Fig. 22. Node Status of Battery After Genetic Execution

Fig 22. shows the battery energy after genetic execution of four nodes which have been recovered {Node1, Node2, Node3, Node4} after the genetic is applied and then all the four nodes have been recharged with 200 mJ.

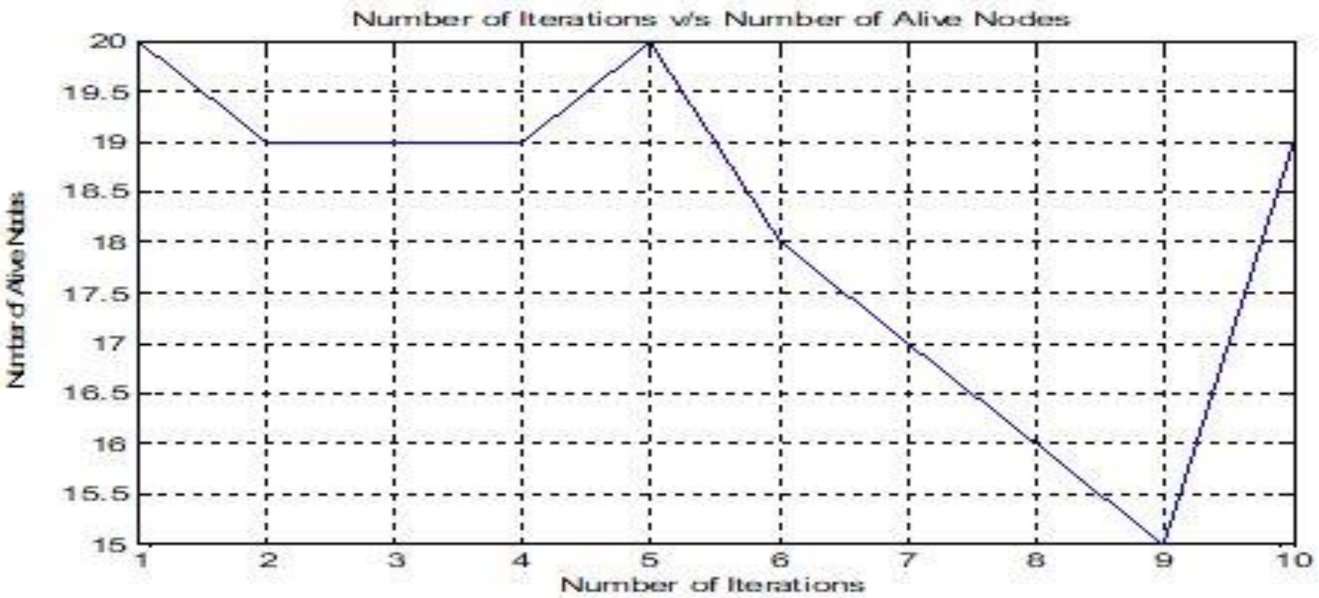

Fig. 23. Number of Alive Nodes Performance

Fig 23. shows the Number of Alive nodes for 10 iterations of routing. After 4 iterations there are 19 alive nodes for the total of 20 nodes. At iteration 5 the genetic algorithm is executed and 20 nodes will become alive. After 9 iterations there are 15 nodes which are alive and then at 10^{th} iteration genetic is executed then after recovery 19 nodes will be alive.

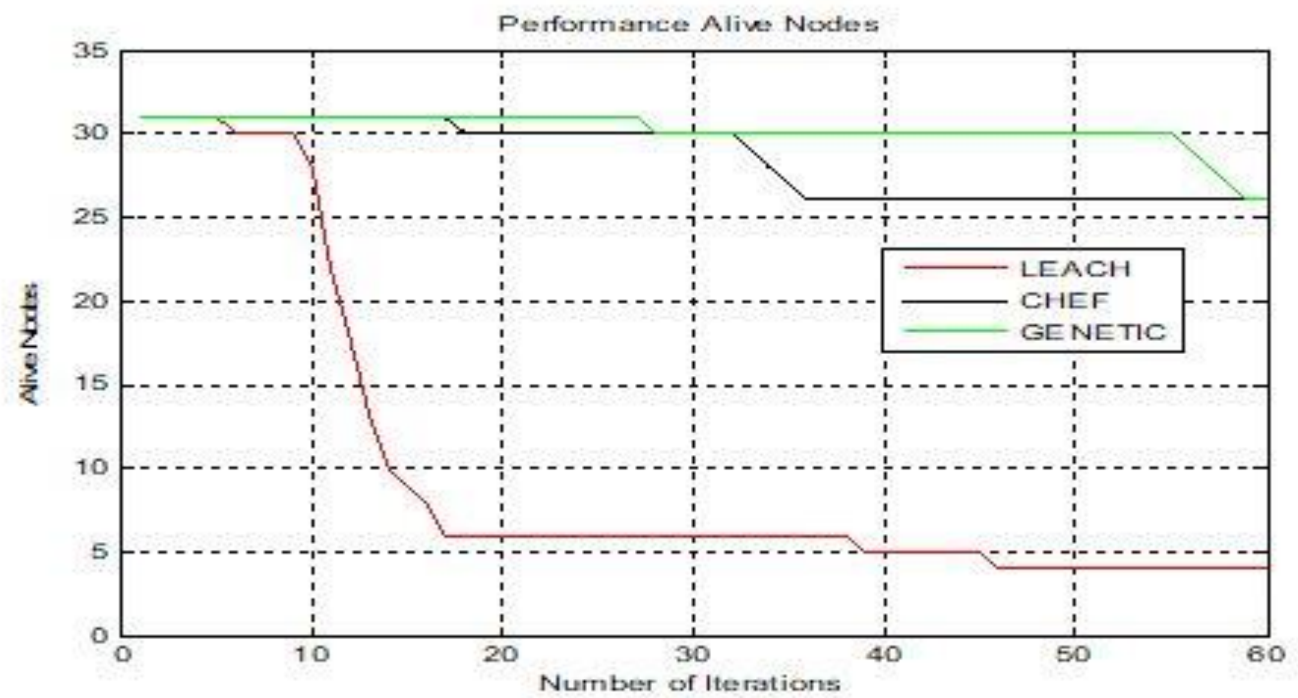

Fig. 24. Number of Alive Nodes Comparision Performance

Fig 24. shows comparision of LEACH, CHEF and GENETIC algorithms. GENETIC is having highest number of alive nodes followed by CHEF and LEACH.

Fig. 25. Comparison of Dead Nodes Algorithms

Fig 25. shows the comparison of dead nodes in the algorithms. GENETIC algorithm has the lowest number of dead nodes followed by CHEF and LEACH. The proposed GENETIC method has the lowest number of dead nodes on an average as compared to CHEF and LEACH.

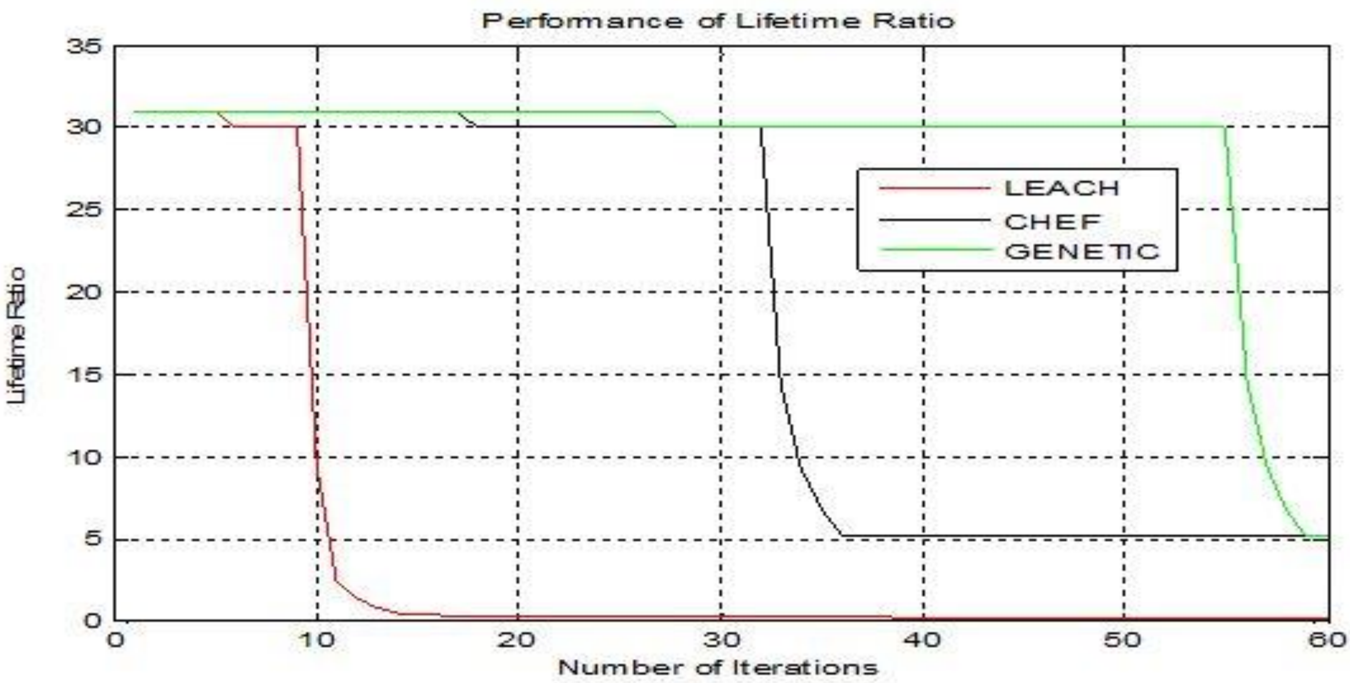

Fig 26. Lifetime Ratio Comparison of Algorithms

Fig 26. shows the lifetime ratio comparison between algorithms. GENETIC algorithm has the highest Lifetime Ratio followed by CHEF and LEACH algorithms.

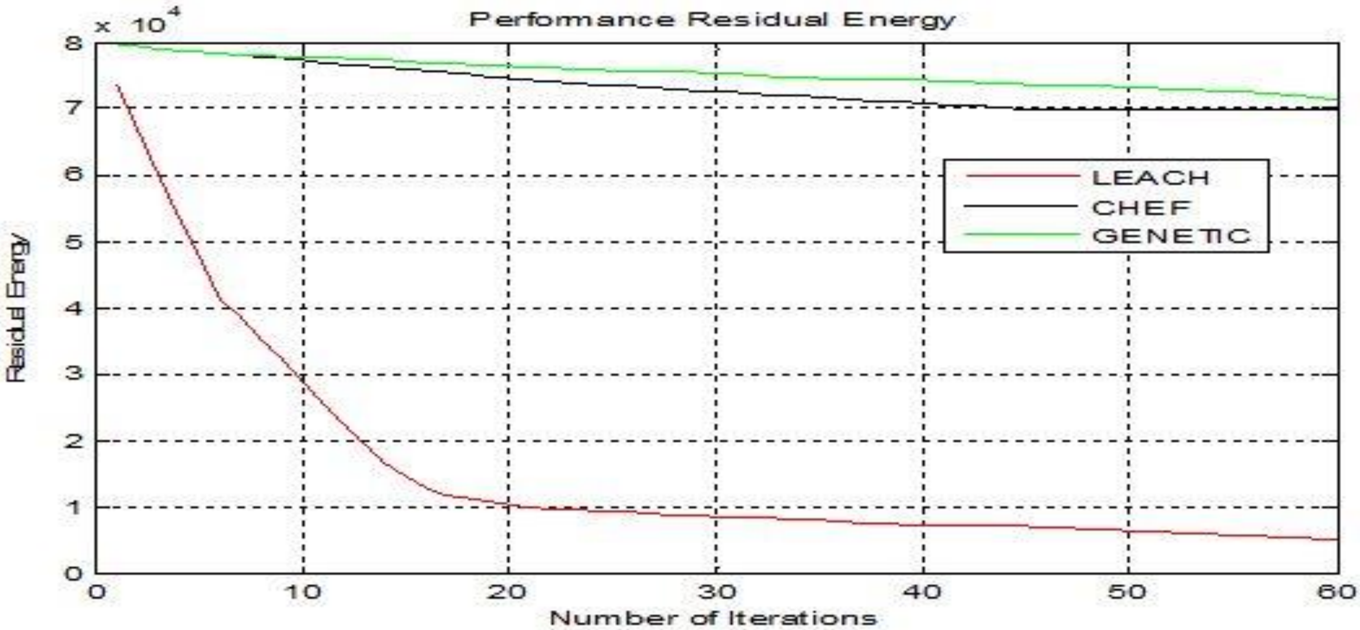

Fig. 27. Comparison of Residual Energy for Algorithms

Fig 27. Shows the performance of residual energy for all the three algorithms. As shown in the fig GENETIC will have the highest residual energy as compared to CHEF and LEACH. As the number of iterations increases the Residual Energy Level for the nodes decreases and GENETIC has the highest amount of residual energy.

VII. CONCLUSION

In this paper, LEACH elects the Leader Node randomly and during routing path formation, there will be lot of back and forth propagation between the base station and normal nodes in the network. CHEF elects the leader node in the manner of multiple constraints of distance and residual energy. The routing path is improved by making use of normal nodes and leader nodes in the routing path. GENETIC algorithm is a periodic protocol which identifies the dead nodes and then executes series of tasks like chromosomes generation, best chromosome formation, crossover and mutation which identifies the nodes to be recovered so that the overall lifetime of network can be improved.

This paper presents the simulation results of comparison between LEACH, CHEF and GENETIC algorithms. These algorithms are compared using various parameters like Number of Alive Nodes, Number of Dead Nodes, Lifetime Ratio and Residual Energy. It is proved that, GENETIC algorithm used to recover the dead nodes and to improve the network lifetime has shown best results compared to CHEF and LEACH algorithms.

VIII. REFERENCES

[1] Muhammad Ali Khan,Arif Iqbal Umar, Babar Nazir, Noor ul Amin, Shaukat Mehmood,Kaleem Habib, "Energy Efficient Clustering Using Fixed Sink Mobility for Wireless Sensor Networks", (IJACSA) International Journal of Advanced Computer Science and Applications,Vol. 7, No. 2, 2016

[2] Sonu Pant,Ramesh Kumar,Ajeet Singh, "Adaptive sink transmission and relocation to extend the network lifetime of wireless sensor network," 3rd International Conference on Advances in Computing,Communication & Automation (ICACCA) (Fall) September 2017.

[3] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", in IEEE Transactions on Wireless Communications, 1(4), 660 – 670, 2002.

[4] Jong-MyoungKim, Seon-HoPark, Young-Ju Han, and Tai-Myoung Chung (2008), "CHEF: Cluster head election mechanism using fuzzy logic in wireless sensor networks",ICACT, 654-659, 2008.

[5] E.H. Mamdani, and s. Assilian, "An experiment in linguistic synthesis with a fuzzy logic 98 controller", International Joumal of Man-Machine Studies, vol. 7, issue. 1, pp. 1-13, 1975

[6] Nguyen, Lan Tien, Xavier Defago, Razvan Beuran, and Yoichi Shinoda, "An energy efficient routing scheme for mobile wireless sensor networks" , Wireless Communication Systems, ISWCS'08, IEEE International Symposium, 568-572, 2008

[7] Wang, Jin, Zhongqi Zhang, Feng Xia, Weiwei Yuan, and Sungyoung Lee, "An Energy Efficient Stable Election-BasedRouting Algorithm for Wireless Sensor Networks"Sensors ,13, (11) 14301-14320, 2013

[8] Yu-Chen, Kuo, Yeh Wen-Tien, C. H. E. N. Ching-Sung, and C. H. E. N. Ching-Wen, "A lightweight routing protocol for mobile target detection in wireless sensor networks" ,IEICE transactions on communications ,93,(12) 3591-3599, 2010

[9] Xun-Xin, Yuan, and Zhang Rui-Hua, "An energy-efficient mobile sink routing algorithm for wireless sensor networks" ,Wireless Communications, Networking and Mobile Computing (WiCOM), International Conference ,1-4, 2011.

[10] Sarma, Hiren Kumar Deva, Avijit Kar, and Rajib Mall, "Energy efficient routing protocol for Wireless Sensor Networks with Node and Sink mobility " , Sensors Applications Symposium (SAS), IEEE, 239 - 243, 2011

[11] Arshad, Muhammad, Naufal M. Saad, Nidal Kamel, and Nasrullah Armi, "Routing strategies in hierarchical cluster based mobile wireless sensor networks", Electrical, Control and Computer Engineering (INECCE), International Conference, 65-69, 2011

[12] Munari, Andrea, Wolfgang Schott, and Sukanya Krishnan, "Energyefficient routing in mobile wireless sensor networks using mobility prediction", Local Computer Networks, LCN , IEEE , Conference , 514-521, 2009

[13] A. A. Taleb, T. Alhmiedat, O. Al-haj Hassan, N. M. Turab, "A Survey of Sink Mobility Models for Wireless Sensor Networks", Journal of Emerging Trends in Computing and Information Sciences, 2013.

[14] Deepa V.Jose and Dr.G. Sadashivappa, "Mobile Sink Assisted Energy Efficient Routing Algorithm for Wireless Sensor Networks",World of Computer Science and Information Technology Journal (WCSIT), ISSN:2221-0741, 5, (2) 16-22,2015

[15] Pantazis, Nikolaos A., and Dimitrios D. Vergados , "A survey on power control issues in wireless sensor networks", Communications Surveys & Tutorials, IEEE , 9, (4) 86-107,2007

[16] Jin Wang, Yue Yin, Jeong-Uk Kim, Sungyoung Lee and Chin-Feng Lai , "An Mobile-sink Based Energy-efficient ClusteringAlgorithm for Wireless Sensor Networks", IEEE 12th International Conference on Computer and Information Technology, 2012

[17] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks" in IEEE Hawaii International Conference on Systems Sciences, 2000.