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Node Recovery and Forward Node Move Algorithm for Network Lifetime Enhancement

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Abstract: ***Wireless Sensor Networks are used for wide variety of applications ranging from monitoring of weather, enemy vehicles across the borders. The critical activities require the nodes to be used for a longer period of time and whenever nodes lose their energy network must be able to recover or replace nodes over a period of time. Before transmitting the data multiple routes are found and then a route is chosen which has lowest distance or end to end delay and high residual energy which affect the life time ratio in the network. The main cause for life time expiring at the faster rate is improper selection of forward node and second important cause occurs if all neighbours are dead. The proposed method performs the Classification of neighbours into super healthy and non healthy nodes and picks the best node which has the highest residual energy. The proposed method also performs the relocation of forward node and recovery of dead nodes to improve network lifetime.***

Keywords: WSN, Residual Energy, Forward Node and Recovery, Network Lifetime.

I. INTRODUCTION

The node is a device which has the following characteristics Battery, Memory and Antenna. Network is treated as the collection of nodes. WSN network is a network in which all the nodes are spread in the single area. The network can be treated as infrastructure less.

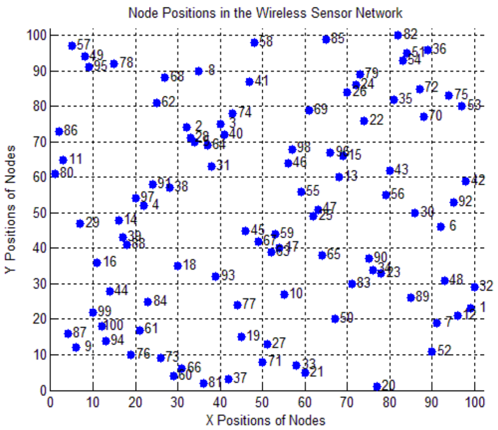

Fig 1: WSN Network

Fig1 shows the Non Hierarchical Network as shown in the figure all the nodes are randomly spread within an area of 100*100 meters.

Wireless Sensor Networks (WSNs) poses formidable design challenges in Energy constrained operation, Communication range, Memory and processing power constraints, Bandwidth constrained links, Dynamic network topologies and Network traffic patterns. These new-found types of networks are largely dictated by application requirements and characterized by severe resource constraints in terms of available energy, computational and communication capabilities. Routing is one of the significant design considerations in WSNs, more especially under severe energy constraints; with the exchange of routing control packets increasing power-consumption from the small, non-rechargeable and hard to replace batteries.

In this paper, we propose *Node Recovery and Forward Node Move Algorithm for Network Lifetime Enhancement* which can improve Network Lifetime. We also conducted simulation results and compared the proposed method with traditional methods for many parameters namely end to end delay, number of hops, energy consumption, residual energy, number of alive nodes, number of dead nodes, Life time ratio and Routing Overhead.

II. BACKGROUND

A. Network Lifetime Ratio

This section discusses several causes which are responsible for reducing the network lifetime

Adhoc Networks have lot of challenges and one important factor that the nodes in adhoc network suffer from is the limited battery capacity [1]. Nodes when their energyis depleting they might shut down. To improve power utilization

Efficiency few nodes must be selected which can act like managers and few nodes can act like staff. The manager nodes can hire staff nodes for packet deliver and make the other staff nodes to sleep. This technique will improve network lifetime by choosing staff periodically. Wireless Sensor Network (WSN)[2] makes use of set of sensors which have low power transceivers for gathering the data. The data is drafted towards the station which acts like a processing centre. If we want to pass the data packets the design must be able to manage it with respect energy of resources. Randomized Grouping of nodes is used to generate a set of cluster heads and by using the grouping energy efficiency is achieved. The grouping assumes that the environment is free from any kind of errors and does not take into Consider the radio propagation effects. Content Centric Networks (CCN)[3] are used for machine to machine communications in the new generation networks. CCN can be used for applications like streaming communication, content services. To achieve enhanced type of data centric network (E3DCN) we need to perform orchestration between packet switching and circuit switching.

Watchdog techniques [3] are used for monitoring the nodes in the network. The nodes perform overhearing which increases the energy consumption for the overall network. Trust Management are used for overcoming these problems using cryptography. Time division based monitoring

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strategy can be used to optimize energy consumption. The problem that this approach faces is as the number of watch dogs increases the energy consumption will be high and nodes will become dead sooner. Online Social Network [4] can have users who have direct friends and indirect friends power control is very important for such applications. A Dijkstra algorithm is used for routing and it effects medium access control layer. Mesh routers are used to perform social network analysis. Caching strategies can be used to improve the content sharing performance. This will reduce the energy consumption in case of data packet delivery. Channel State Information [5] and location of eavesdroppers is important factor for secure routing. A random jamming algorithm can be used to exploit non idealises of a eaves dropper which can detect the node with out location knowledge. Wireless Sensor Networks [6] can be used for detecting data for various applications like civilian, military, seismic measures etc. To perform all the tasks in various applications sensor will consume more energy and there shall be reduction in energy of each sensor. Honey bee optimization can find an optimal route with low cost. This is done by grouping nodes based on energy clusters and takes the concepts of artificial bee colony algorithms. The energy is important constraint in Wireless Sensor Network [7]. A heuristic function containing transmission distance, transmission direction and residual energy can be used to find an optimal path for data transmissions. The environment [8] which has obstacles most energy is waisted due to sensing, communication and movement. Consider the area in which nodes are spread can be divided into a matrix of minute cells. The entire nodes are differentiated based on weights. The shortest path algorithm can be applied on the graph to reduce overall energy consumption of the network.

Underwater Wireless Sensor Network (UWSN) [9] contain small sensor nodes which have limited battery and limited memory in underwater environment. Radio waves are not used for communication in UWSN networks and acoustic channel are used for communication under lakes. The constraints in UWSN are number of packets in a given time, Time taken and loss of data. Energy efficiency is very important factor. Two algorithms are used and compared for various parameters. Networks are connected nodes with varied positions [10] and they must handle network division’s long delays and dynamic mobility. The connection and weights [11] of the nodes contribute the residual energy and this will reduce with respect to time. The algorithm makes use of multi hop techniques, dynamic mechanisms and self configuration without any need of infrastructure. The protocol [12] finds the route based on delay and energy. The most important factor of energy consumption in sensor network is due to antennas and signals. Transmission and reception of packets will get impacted due to energy levels.

As the energy reduces it affects the number of transmitted and received packets. The optimization framework strategy [13] based on Branch and Bound algorithm is used to route the packets from each source to sink node based on optimal power allocation and hops. The power levels for each node are selected from predefined values. Adaptive energy harvesting is used to increase the network lifetime. The data transmission [14] will be limited because of moment for nodes. As the distance travelled by the node increases it will have increase the amount of delay and produces high throughput. Cluster heads are elected based on kleinrock independence and burkes theorem. Electronic devices [15] in vehicles and on board sensors to perform crowd sourced data collections. The collected data lacks study of effective utilization for personal prediction. The missing data can be recovered from sparse data but it is a challenging process. Network function virtualization [16] (NFV) implements network functions which run on a group of servers to provide flexibility and agility. The severs can be turned off in a low traffic period to save energy consumption.

The approaches do not talk about recovery of dead nodes or periodic systematic sleep modes for the nodes. Hence the concentration can be done more in this area to future improve the lifetime, routing overhead, end to end delay. Based on the algorithms present in the literature one more way is suggested in which sink relocation can be combined with genetic in order to improvise overall network lifetime periodically.

Major Causes of Network Lifetime

[1] Energy Depleting Nodes who lose their energy faster
[2] Selection of improper forward node during routing
[2] Improper radio propagation model

How Network Lifetime can be Improved

[1] Sleep Mode for the nodes periodically
[2] Caching techniques can be used
[3]The algorithm which improves the network lifetime either can make use of a route which has highest residual energy.

B. Sink Relocation Techniques

In WSN the nodes sense pressure, temperature and monitor certain activities. The sensed data is sent to the destination node or a controlling station based on nodes which are at fixed position or based on nodes which move whenever the neighbours have less energy. The transfer of sensed data based on fixed nodes is called as stationary approach. The network will function until all nodes loose there energy levels. For a moving node approach the network will remain functional until most of the nodes become dead because the mobile node can relocate itself to a different position if all the nodes in its communication range fall below threshold. The mobility based models has been proposed in [17-20]. EASR algorithm [21] divides nodes into multiple types based on the residual energy levels for nodes and then performs relocation of the node if all the neighbours are of type 3.

III. PROPOSED METHOD

The Section describes the Network Model, Perform Network Lifetime Analysis, Energy Consumption Model, Energy Consumption Analysis, Transmission Range adjustment, classify nodes into different types. Recovery of dead nodes using Genetic Process, and actual routing process using NRFRMA.

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A. Network Model

Consider a space with the end points namely $x_{\min}, x_{\max}, y_{\min}$ *and* $y_{\max}$. The node represented by a 3 parameter $(B, M.A)$ Battery, Memory and Antenna are set of entities which must satisfy the boundary limitations $x_{\min} \geq x_i \leq x_{\max}$ and $y_{\min} \geq y_i \leq y_{\max}$. x_i, y_i represents position of the i^{th} node in the network. Since one node cannot take the same physical position as that of other node in the network. The network model of Wireless Sensor Network (WSN) must satisfy the condition $(x_n, y_n) \neq (x_m, y_m)$. x_n, y_n Represents the position of n^{th} node and x_m, y_m represents the position of m^{th} node in the network. For the network model there will be many nodes N_{nodes} which must exist in order perform the routing process across various layers of protocol stack. Finally each of the node must be described using the 3 unique attributes namely Node Id and respective position of node in the network. If there are N_{nodes} then a matrix must be created as

Node	Position
1	(x_1, y_1)
2	(x_2, y_2)
N_{nodes}	(x_n, y_n)

Algorithm1: Network Generation for simulation

Input: $N_{nodes}, x_{\min}, x_{\max}, y_{\min}, y_{\max}$

Output: A set of node information NI

Description:

a) $i = 1$

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

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

$x_i = v$

any v which satifies

$x_{\min} \leq v \leq x_{\max}$ & $v \neq x_h$

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

$y_i = v$

any v which satifies

$y_{\min} \leq v \leq y_{\max}$

and $v \neq y_H$

Where,

x_H – *history of x positions previously assigned*

&

y_H – *history of y positions previously assigned*

e) Form a tuple in the format

$(i, (x_i, y_i))$

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

Node	Position
i	(x_i, y_i)

g) $i = i + 1$

Note – Internally each value of i has a unique address for communication

Fig 2: Network Model

The Node Deployment module is responsible for generating the various positions of such nodes in the network from the simulation perspective. The Network model can be formed using the algorithm1 as presented in the fig1.

The above process must each and every time result in a different value as the nodes can also be mobile in nature. The network model has been applied for 100 nodes and they result in the graph as shown in the fig2

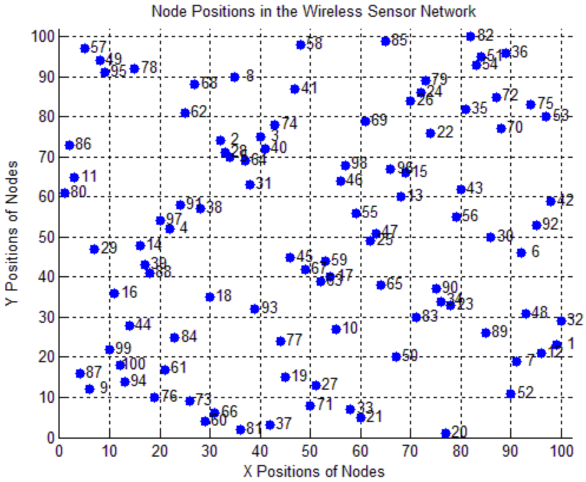

Fig 3: Network Model graph for Iteration1

As represent in the fig 3 each node has its own position in the network with $x_{\min} = 1, x_{\max} = 100, y_{\min} = 1$ *and* $y_{\max} = 100$ each of the 100 nodes in the network have their own id and positions

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in the network which satisfies the objective function $1 \le x \le 100$ *and* $1 \le y \le 100$. Also any two nodes picked in the network does not have the same position for example as shown in the fig2 Node 9 is around 11 y and 9 x from the reference point (1,1). Node 52 is present at 10 y and 90 x. Hence Node 52 follows the condition specified in the network model $x \ne X_H$ & $y \ne Y_H$.Now if we observe the same nodes after some period of time then one can see can the changes in the position of nodes for handling the mobility scenario as shown in the fig3.

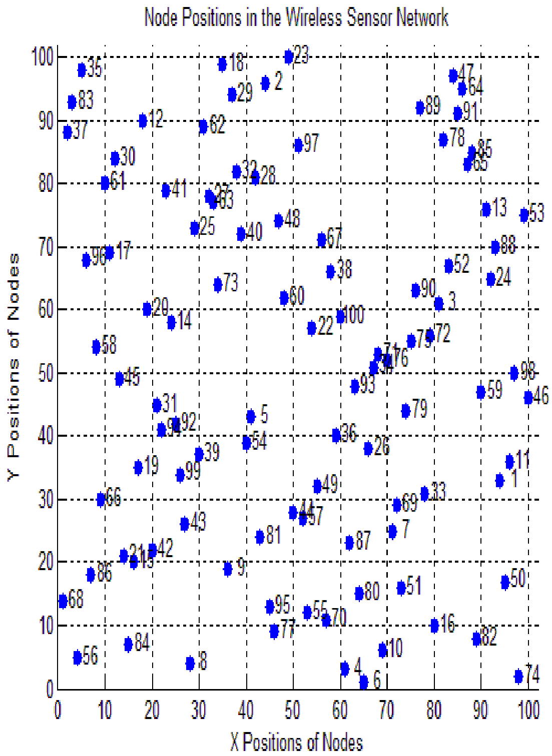

Fig 4: Network Model for Iteration=2

Fig 4 depicts network model after a period of time in the same area of 100*100 as described fig2 all of the nodes satisfy the objective functions also Node 9 and Node 52 are now at different positions as compared to previous iteration. The same is summarized in the following table

Node Id	Position in Iteration1	Position in Iteration2
9	(9,11)	(36,9)
52	(90,10)	(83,67)

As described in the above table Node 9 and Node 52 have changed their positions using the same algorithm1 over a period of time. The network model can be future be evaluated by observing the position of nodes over N iterations. The fig 4 shows the change in position of nodes for a period of 5 iterations.

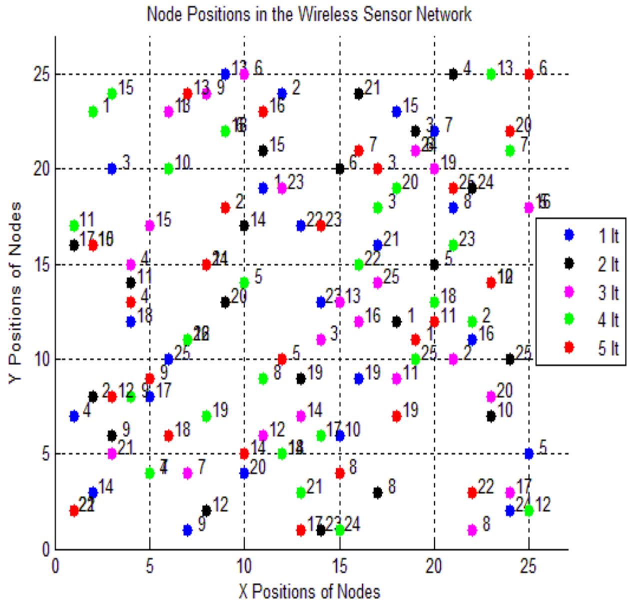

Fig 5: Position Changes of all Nodes

Fig 5shows the changes in the position of nodes in the network as shown in the fig the network model is run for a period of 5 iterations by considering 25 nodes in an area of 25*25. Blue represents the position of nodes for iteration 1 , Black represents position of nodes for iteration2 , Pink represents position of nodes for iteration3, green represents position of nodes for iteration 4 and finally RED represents the position of nodes for iteration 5.

B. *Network Lifetime Analysis*

Network lifetime is the key characteristics for the network. In order to propagate the packets regularly in the network the lifetime is very important. Many definitions of network lifetime exist in the literature [22] which considers different structures like triangle and regular quadrangle topologies. As per the Mean Square Error [23] function it's not required for all nodes which are dead to be recovered but at least those many nodes must be alive such that the network can function. In this work we consider rectangular network model and concentrate mainly on the network lifetime given by equation 1.

$$LTR = \frac{N_{alive}}{N_{dead}} \qquad (1)$$

Where,

$LTR = Lifetime\ Ratio$

$N_{alive} = Number\ of\ Alive\ Nodes$

$N_{dead} = Number\ of\ Dead\ Nodes$

Let B represents the initial battery energy for all the nodes in the network. If the value of remaining energy is less than the 4 times the initial energy i.e $B/4$ then the node is treated as dead otherwise the node is treated as alive. The energy reduction happens when ever any nodes participate in routing. The updated energy is a linear model which can be computed using the following equation

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$$UE = CE - E_c$$
$$Where,$$
$$CE = current\ energy \quad (2)$$
$$E_c = energy\ consumption$$

The energy consumption can be computed using the model described in the next section.

C. Energy Consumption Model

The entire energy consumption modelling is performed based on the radio propagation [23-25] models given in the literature. Consider that there are two nodes m and n located at a distance of d . Let the number of bits transmitted for the node n be represented by N_b . The node has majorly main components like transmitter component and amplifier component

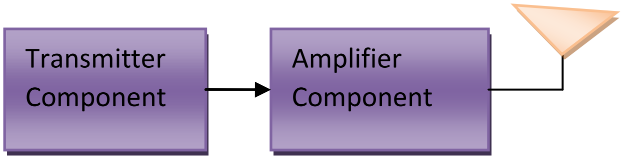

Fig 6: Major Energy Dissipation Components

The energy required for transmitting N_b bits is given by the following equation

$$E_{trans}(N_b, d) = N_b * (E_{transmitter} + E_{reciever} * d^n) \quad (3)$$

Where,

$$N_b = Number\ of\ bits$$
$$d = range\ between\ nodes$$
$$E_{transmitter} = energy\ required\ by\ transmitter\ circuit$$
$$E_{reciever} = energy\ required\ by\ reciever\ circuit$$
$$n = a\ constant\ integer$$

The energy required by the node receiving the N_b bits is given by

$$E_{reception} = N_b * E_{tranmitter} \quad (4)$$

The total energy consumed for transmitting N_b bits over a distance of d can be given as

$$E_c = E_{trans} + E_{reception}$$
$$E_c = N_b(E_{transmitter} + E_{reciever} * d^n) + N_b * E_{transmitter}$$
$$E_c = N_b E_{transmitter} + N_b E_{reciver} * d^n + N_b * E_{transmitter}$$
$$E_c = 2 * N_b E_{transmitter} + N_b * E_{reciever} * d^n$$
$$E_c = N_b(2 * E_{transmitted} + E_{reciver} * d^n) \quad (5)$$

As per the classical energy consumption model [45] [26] the following standard values are assumed during energy consumption computation.

Table 1: Energy Consumption Values

Mode of Operation of Antenna	Energy Consumption
$E_{transmitter}$	50 nJ/bit
$E_{reciever}$	100 pJ bit/m

D. Energy Consumption Analysis

The residual energy of the node in WSN goes down whenever the nodes participate in routing. Consider a routing path as below

$$a ---> f ---> m ----> z$$

Where a is acting like a sender node and z being the node which receives the data.

The energy consumed between nodes $a ---> f$ by using a distance of 30m, Number of bits transmitted as 100 and n=2 along with values given in the table 1 can be computed as below

$$E_c = 2 * N_b E_{transmitter} + N_b * E_{reciever} * d^n$$
$$E_c = N_b(2 * E_{transmitted} + E_{reciver} * d^n) \quad (5)$$
$$E_c = 100\ (2 * 50\,nJ + 40\ pJ * 30^2) = 1.3600\text{e-}005$$

Next there is a transmission process between $f ---> m$ hence the energy of node f also will come down. Let 40 m be the distance between the nodes then the energy consumption is given by

$$E_c = 100(2 * 50\,nJ + 40\ pJ * 40^2) = 1.6400\text{e-}005$$

As per the computation the energy consumption increases as the distance between the nodes increases. In a similar fashion energy is also consumed for node m when it transmits data to destination z .

The energy consumption as the factor of distance can be described in the fig 7

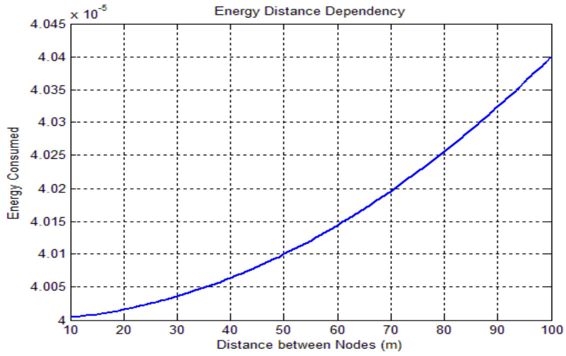

Fig 7: Energy distance dependence

Fig 7 shows the dependence between energy and distance. As shown in the fig as the distance increases the energy consumed also increases. The above fig is obtained with $N_b = 400$, $E_{transmitter}$ and $E_{reciever}$ of table1 and distance is varied between 10 to 100 m.

As per the equation 2 if the initial energy of all the nodes remains same in the network say for example 3000 mJ then the energy of node f which has been used in the routing path will have its current energy as

$$UE_f = CE_f - E_c = 3000 - 1.3600 = 2998.6$$

Hence as the same nodes participate in the routing process they eventually become dead if the energy of nodes reduces by $B/4$. In the case of node f it is 750.

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The variation for the case of 100 nodes as the factor of number of times they participate in routing in their remaining energy with initial value of 3000 mJ can be observed in the fig7

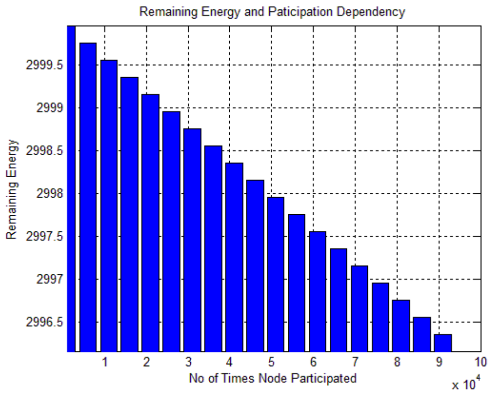

Fig 8: Residual Energy and Participations

As shown in the fig8 a function of no of times node participated in routing versus the remaining energy of nodes in the network as the nodes participate in the routing path more number of times there remaining energy also reduces. Hence a point will be reached at which the energy reduces so that the node becomes dead.

E. Transmission Range

The optimal transmission range γ [46] by can be computed by using Lagrange multiplier using the equation 5

$$d_i = \frac{D}{((\sum_{i=1}^{n}(1/i)) * N_{pack})}$$

Where,

$$N_{pack} = Number\ of\ packets$$

$$D = total\ distance\ across\ nodes$$

$$n = total\ number\ of\ nodes$$

F. Types of Nodes

The algorithm used in the paper considers two kinds of nodes known as type1 and type2 nodes. Type1 nodes are those whose energy is higher than $B/4$ and Type2 nodes are those whose energy is less than $B/4$. The same is illustrated in the fig 8.

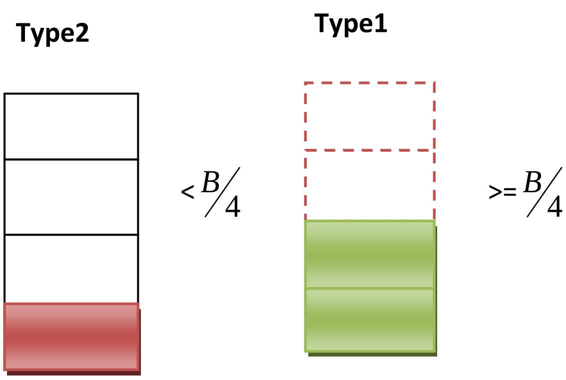

Fig 9: Different types of nodes

Fig9 shows the different types of nodes as shown in the fig the Type1 represent the node which has energy higher or equal to B/4 and Type2 are those nodes whose energy is less than B/4.

G. Node Recovery using Genetic Process

1) The controlling station will send the control packet with a status A to the nodes present in the transmission range γ
2) The set of nodes will REPLY with the status has $PACK$ or $NACK$. PACK indicates that the node energy is of type1 and NACK indicate that the node has the energy of type2.
3) The nodes which received the control packet of status A will send the status B to the nodes which are neighbours of 1 hop nodes found in step1.

1) Genetic process is triggered for every T iterations in order to recover the nodes which are faulty in nature
2) Find the count of number of faulty nodes in the network. Faulty nodes are set of nodes which do not have sufficient amount of energy required for transmission. The step3 will get executed if the number of faulty nodes becomes higher than zero.
3) A set known as chromo zone is generated which depends on the number of faulty nodes. The chromosome size is equal to number of faulty nodes.
4) Consider a set of four chromosomes $\{CZ1, CZ2, CZ3, CZ4\}$
5) Suppose the set of nodes {5,9,15,20,23,35,40,45,55,60}. The size of faulty nodes is 10 then there are four chromo Zones which are randomly generated with the values of zero and ones as given by the following values

$$CZ1 = \{0,0,1,0,1,1,0,1,1,0\}$$
$$CZ2 = \{1,1,0,0,0,1,0,1,0,1\}$$
$$CZ3 = \{0,0,1,0,1,1,0,1,0,1\}$$

and

$$CZ4 = \{1,1,0,0,0,1,0,1,1,0\}$$

The chromo zones can be graphically represented in fig8

As shown in the fig there are 4 chromo zones arranged together in pairs of 2.

The cross over divides the 10 binary digits into 2 equal half and then another 10 binary digits into 2 equal half. Finally opposite binary digits are exchanged.

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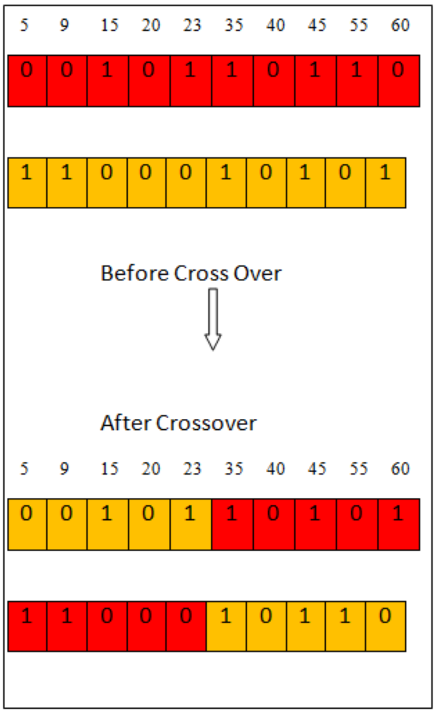


Fig 10: Cross over Application

6) Each binary digit is called as the gene for the chromo zone. The two chromo zone formed after crossover have 10 digits in each chromo zone. The binary digit is selected randomly and then flipped to perform mutation. The mutation process is as shown in the fig 10

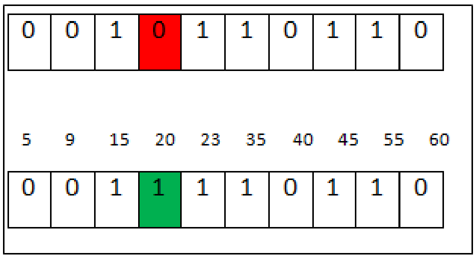


Fig 11: Mutation

Fig 11 shows the mutation process in which the 0 value is flipped with a value of 1.

H. NRFRMA Routing Process

The Node Recovery and Forward Node Move Algorithm (NRFRMA) routing process finds the neighbours first in all the directions and then it picks the neighbours in a particular direction. After the neighbours are found the initiator node sends the control packet and finds the node whether it is healthy or non healthy in terms of energy. After that the node which has the highest remaining energy is chosen as the next forwarding node. Like this process is repeated until destination node is reached. Suppose all the nodes are non healthy the intermediate node relocates itself towards the destination point. Here intermediate nodes indicates the current source node used during the route discovery process when all neighbours are dead. In order to improve network lifetime periodically genetic algorithm is applied to recover the dead nodes in the network. The proposed algorithm can be depicted as fig 11.

IV. Numerical Analysis for Route Discovery

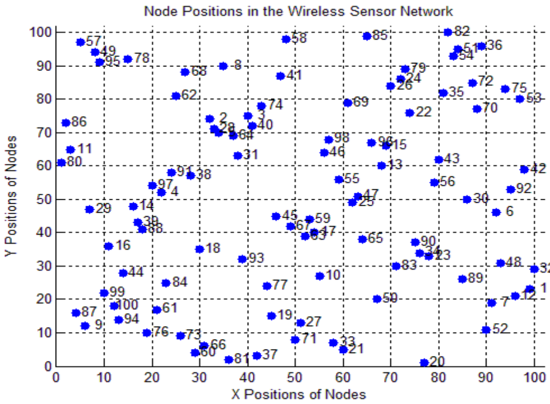
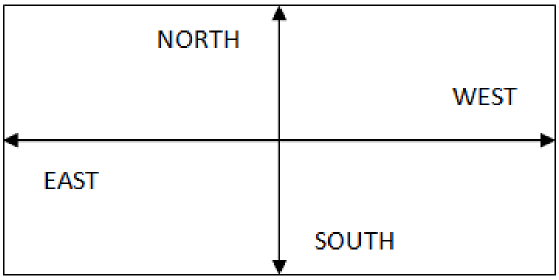


Fig 12: Network for Numerical Analysis

The assumption is that initially all the nodes have the same intial energy of 1000 mJ. A node is said to be faulty node if the energy of node is below 250mJ.

Fig 12 shows the network for numerical analysis. Let Node 9 is the source node and Node 36 is the destination node. The Node 9 finds the neighbour nodes within a transmission range of 50 m are {87,100,94,99,44,84,61,76,73,55,16, 88, 18,81}. The nodes belong to all the four sectors north, south, east, west. The neighbours can be divided into different sectors as shown in the below fig



The entire area is divided into four regions – North East, East South, South West and West North. The destination is at the West North region and hence the neighbours in this region are chosen to move forward. The neighbours sub set are {100,94,99,44,84,61,16,88, 18,81 }. Let us assume that routing has happened and following are the energy levels for the various nodes

Table 2: Energy Levels for Neighbours of Node9

Node	Remaining Energy (mJ)
100	750
94	340
99	150
44	175
84	750
61	150
16	340
88	500
18	550
81	120

The node which has the highest energy i.e 750 mj are Node 84 and Node 100.

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Therefore any one of the node can be chosen in order to move forward for example Node 84.

Algorithm: Route Discovery Process
Input: source node, destination node, transmission range
Output: Path between sources to destination node with intermediate node shift
Details

1) A set $\{SN, DN\} \in N$ acts as input
2) The entire area is divided into four different sectors $\{S_N, S_S, S_E, S_W\}$
3) The sector which is closer to destination is chosen $S_i\ \varepsilon\ \{S_N, S_S, S_E, S_W\}$
4) Find the set of nodes belonging to sector S_i as $\{n1, n2, ...nn\}$ $ni \varepsilon N$
5) The initiator SN will send the RREQ and then obtain the remaining energy levels of the nodes in the set $\{n1, n2, ...nn\}$ $ni \varepsilon N$
6) Find the set of nodes whose energy levels are higher than $B/4$, B *in initial energy* from the set of nodes $\{n1, n2, ...nn\}$ $ni \varepsilon N$ as $\{n1, n2, ..., nm\}$ with energy levels $ni\ \varepsilon\ N\ and\ m < n$
   $el = \{e1, e2, ..., em\}$
   $ei = energy\ level\ of\ a\ node\ i$
   $each\ ei > B/4$
7) Pick a node which has the highest energy level and if more than one node has the same highest energy then pick one of them randomly

$e\max = \max(e1, e2, e3, ...em\}$

selected node is the node which has emax

$SN = ni\ \varepsilon\ N\ \&\ e = e\max$ if $len(e) = 1$

$SN = any\ \ ni\ \ \& e = e\max\ if\ len(e) > 1$

8) Suppose there are no nodes whose energy is higher than $B/4$ then the current source nodes moves towards the destination node with 1 hop distance in appropriate location
$S_i\ \varepsilon\ \{S_N, S_S, S_E, S_W\}$

9) The steps from 1 to 8 are repeated until destination is reached.

Note – If the route discovery has been performed for a period of T iterations then genetic algorithm is triggered and then dead nodes are recovered.

The Node 84 will again find its neighbours in the various sectors as{16,29,14,88,93,31,45,67,59,83, 7,18,93,77,19, 27,71,38,91} and the neighbours which are in North West sector are {18,93,38,91}.The remaining energy levels suppose are given by the following data.

Table 3: Energy Levels for Neighbours of Node84

Node	Remaining Energy(mJ)
18	550
93	220
38	245
91	200

Table shows that the nodes Node 93, Node 38 and Node 91 are having the lowest battery levels and then Node 18 has the energy which is better than threshold 250 mJ. Hence the only option for moving forward in this case is Node 18. The routing path until now is
Node 9 → Node 84 → Node 18

The neighbours of Node 18 are found in all the sectors {84,44,29,14,38,97,4,91, 38,93,77,19,45,59,67,17}. The nodes which are in the sector of North West are {45,59,67,17}. The energy levels for the nodes can be assumed as follows

Table 4: Energy Levels for Node 18

Node	Remaining Energy (mJ)
45	150
59	180
67	200
17	220

The table shows the energy levels for Node 18. As shown in the fig all nodes have the energy lesser than threshold hence the node 18 has to move from its position towards the destination node by the factor of transmission range. Node 18 has the initial position for the node as (30,35) and now would have relocated itself to (80,85). This movement can be illustrated as in below fig13.

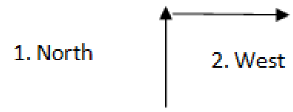

Fig13: Node Movement towards destination with Type II nodes in neighbour sector

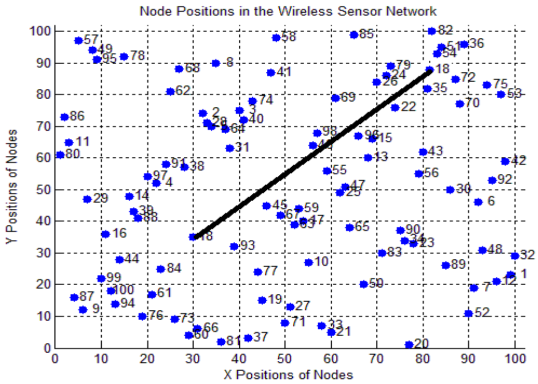

Fig 14: New Position of Node 18 after relocation

Fig 14 shows the positional change for Node18 from the initial to the new position. Finally now Node 36 is within the transmission range of Node 18 and final route is formed as *Node 9 → Node 84 → Node 18 → Node 36*

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V. Energy Consumption on Route

Consider that the energy levels of the nodes which participated before performing route discovery are as follows

Table 5: Energy Levels before Routing

Node	Remaining Energy (mJ)
9	1000 mJ
84	750 mJ
18	550 mJ
36	1000 mJ

Consider that the distance between the nodes depicted in the below table

Table 6: Distance between Nodes

From Node	To Node	Distance (m)
9	84	35.5
84	18	24.56
18	36	10.74

The energy consumed between 9 and 84 can be computed by assuming the transmission energy as 20 nJ and generation energy as 10 nJ.

$$E_{c(8,94)} = 2*20+10*(35.5)^2 = 750\ nJ$$

The remaining energy computations between Node 84 and Node 18 are also computed and depicted in the table.

Table 7: Energy Consumed Computation all Nodes

Nodes	Energy (nJ)
(9,84)	750 nJ
(84,18)	531.2 nJ
(18,36)	254.8 nJ

As depicted in the above table the energy consumed between Node 84 and Node 18 is 531.2 nJ and that between Node 18 and Node 36 is 254.8 nJ. The overall energy consumption can be linear addition across the nodes participating in routing. The overall energy consumption is 1536 nJ.

VI. NETWORK LIFETIME IMPROVEMENT AS COMPARED TO EASR ALGORITHM ANALYSIS

For the discussion the energy required for transmission is 20 mJ and energy required for generation is 10 mJ.

Forward Node Pick Improvement

The proposed method picks the intermediate node based on the highest remaining energy levels as compared to picking any from the type II in EASR which provides an improvement factor in the lifetime ratio. For example the proposed method has picked Node 84 because the remaining energy is higher than threshold and highest among the neighbours 750 mJ. The updated energy for Node 84 will be (750mJ- 750nJ) =

The EASR divides the nodes into 3 types and it could have picked Node 94 which has the remaining energy as 340 mJ. The distance between Node9 and Node 94 is 40.5 then the energy consumed will be 1660 nJ. The updated energy for Node 94

Now if and for EASR it would be (340mJ- 1660nJ). Hence Node 94 is closer to becoming dead node as compared to Node84 as given in proposed method.

Node Recovery by Genetic Periodically

Consider that there are 10 nodes in the network and then routing process has happened around 200 times. The Table 8 shows the remaining energy for the nodes in the network. The next assumption is that the genetic algorithm is triggered each time for 200 iterations periodically i.e for iteration number 200 and then 400 etc. As shown in the Table 7 the dead nodes are Node2, Node3, Node4, Node5, Node6 and Node7.

Table 8: Remaining Energy for the Node after 200 iterations

Node	Remaining Energy(mJ)
1	760
2	300
3	150
4	175
5	175
6	167
7	187
8	400
9	450
10	550

The existing EASR algorithm does not have the Node recovery process and hence after 200 iterations more number of nodes will become dead where as the proposed method will recover few of 6 dead nodes using genetics. For example say Node 2, Node 4 and Node 6 are recovered by using process described in VIII. After recovery of the dead nodes the remaining energy levels are given in Table 9.

Table 9: Remaining Energy for the Node after 200 iterations after genetic algorithm is applied.

Node	Remaining Energy(mJ)
1	760
2	1000
3	150
4	1000
5	175
6	1000
7	187
8	400
9	450
10	550

Table 8 shows that the nodes namely Node2, Node4 and Node6 have been reinitialized with the energy of 1000 mJ. This is how the network lifetime is increased.

VII. RESULTS AND ANALYSIS

In this section there is comparison between the proposed method with other methods namely EASR [26], Stationary [29] and One Step Algorithm [28].

The experimental set up assumes the following.

Table 10: Input Parameters

Parameter	Parameter Value
Number of Nodes	100
Transmission Energy	40 m
Transmission Energy	20 mJ
Generation Energy	10 mJ
Topology	Random
Number of iterations	100
Attenuation Factor	0.7

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The above table indicates the input parameters used in the MATLAB simulation. The proposed method i.e NRFNMA has been compared with several existing methods namely Stationary, One Step and EASR for various parameters namely Number of Alive Nodes, Number of Dead Nodes, Lifetime Ratio, End to End Delay and Routing Overhead

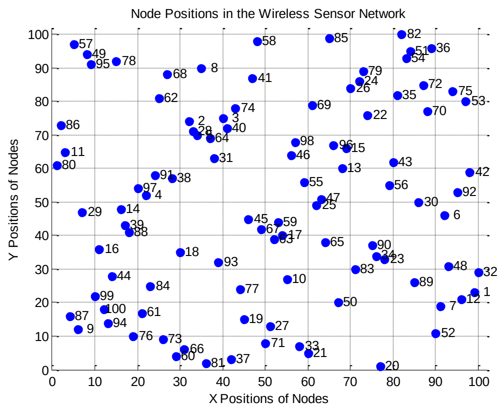

Fig 15: Node Deployment Algorithm

Fig 15 shows the position of nodes in the network. As shown in the fig there are 100 nodes in the network which are randomly spread in the 100 * 100 area. Node 9 has been placed at the position (6, 12), Node 36 is at the position (89, 96).In a similar fashion all the remaining 98 nodes are placed in the network.

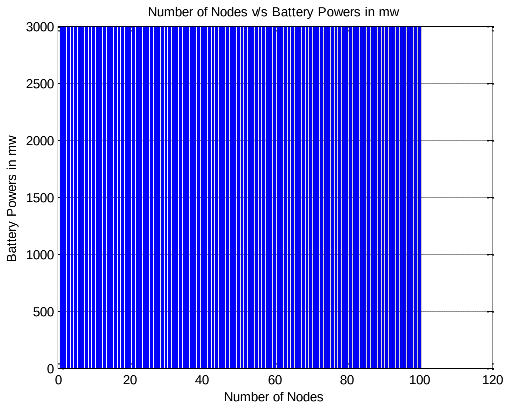

Fig 16: Battery Power of Nodes in the Network

Fig 16 shows that all the 100 nodes have been initialized with the same amount of energy of 3000mJ.

A. *Number of Alive Nodes*

This is defined as the count of set of nodes whose battery level is greater than or equal to B/4 Where B is initial Battery Power

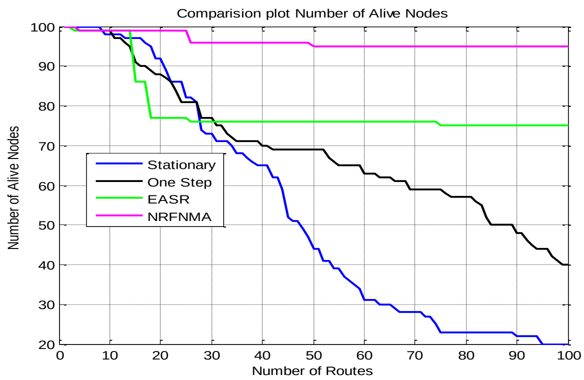

Fig 17: Number of Alive Nodes

Fig 17 shows the Number of Alive nodes in the network. As shown in the fig the number of alive nodes for the proposed NRFNMA method is always high followed by EASR, One Step and Stationary. At the end of 100 iterations the Number of Alive Nodes are 20 for Stationary algorithm, 40 for One Step algorithm, 78 for EASR algorithm and finally 96 for NRFNMA method.

The following table summarizes the number of alive nodes at the end of 100 iterations.

Table 11: Number of Alive Nodes

Algorithm	Number of Alive Nodes
Stationary	20
One Step	40
EASR	78
NRFNMA	96

B. *Number of Dead Nodes*

This is defined as the count of set of nodes whose battery level is less than B/4 Where B is initial Battery Power

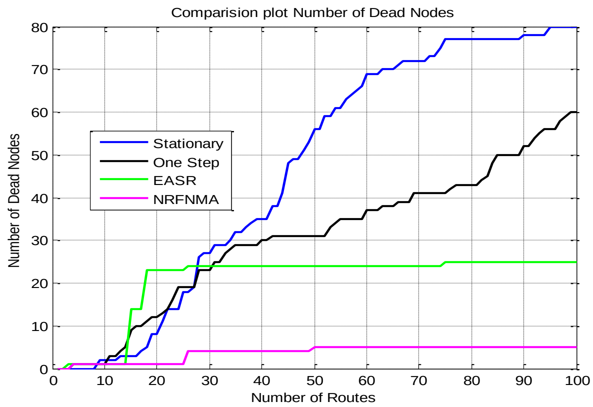

Fig 18: Number of Dead Nodes

Fig 18 shows the Number of Dead nodes in the network. As shown in the fig the number of dead nodes for the proposed NRFNMA method is always low followed by EASR, One Step and Stationary. At the end of 100 iterations the Number of dead Nodes are 80 for Stationary algorithm, 60 for One Step algorithm, 22 for EASR algorithm and finally 4 for NRFNMA method.

The following table summarizes the number of Dead nodes at the end of 100 iterations.

Table 12: Number of Dead Nodes

Algorithm	Number of Dead Nodes
Stationary	80
One Step	60
EASR	22
NRFNMA	4

Lifetime Ratio

$$LTR = \frac{N_{alive}}{N_{dead}}$$

Where,

$LTR = Lifetime\ Ratio$

$N_{alive} = Number\ of\ Alive\ Nodes$

$N_{dead} = Number\ of\ Dead\ Nodes$

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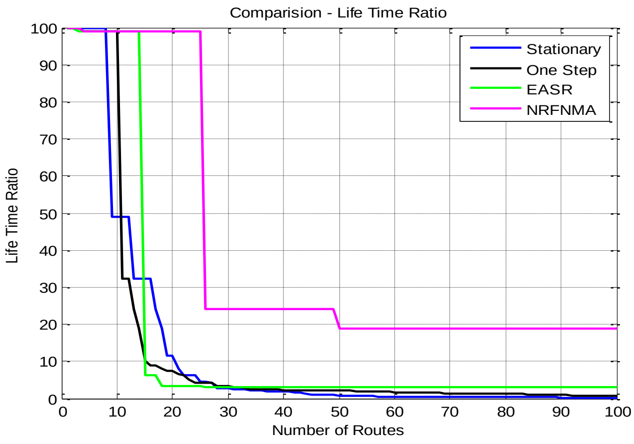

Fig 19: Lifetime Ratio

Fig 19 shows the Lifetime Ratio comparison. The proposed NRFNMA algorithm has the highest life time ratio followed by EASR, One Step and Stationary. At the end of 100 iterations Stationary method has the life time ratio of 0.25, One Step method has the life time ratio of 0.66, EASR method has the life time ratio of 3.54 and finally NRFNMA has the life time ratio of 24.

C. *Residual Energy*

It is defined as the remaining energy of the network. The Residual Energy of the network is given by

$$RE = \sum_{i=1}^{N_{nodes}} RE_i$$

Where,

$$N_{nodes} = total\ \ number\ \ of\ \ nodes$$

$$RE_i = \text{Residual}\ \ Energy\ \ for\ \ i^{th}\ \ node$$

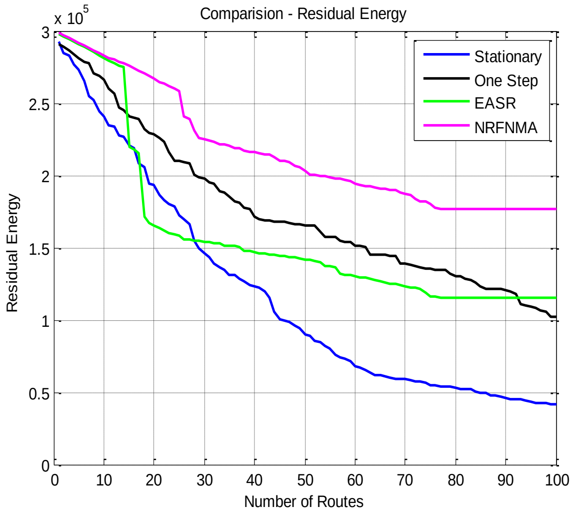

Fig 20:Residual Energy of Nodes

Fig 20 shows the residual energy of nodes in the network. The proposed NRFNMA method has the highest residual energy followed EASR, One Step and Stationary algorithm. Intially all the algorithms have the same energy levels of 3000 mJ. Finally at the end of 100 iterations also NRFNMA has the highest residual energy followed by remaining algorithms.

The residual energy at the end of 100 iterations can be defined as follows.

Table 13: Residual Energy Comparision

Algorithm Name	Residual Energy
Stationary	0.4*10^5
One Step	1.2*10^5
EASR	1*10^5
NRFNMA	1.8*10^5

Energy Consumption

The total energy consumption is given as follows

$$TE = \sum_{i=1}^{l} E_c(i)$$

Where,

$$l = Number\ \ of\ \ Links$$

$$E_c(i) = Energy\ \ consumed\ \ across\ \ i^{th}\ \ link$$

The energy consumed by the i^{th} link given by

$$Energy\,consumption = 2\ E_{tx}\ + E_{gen}\ d^{\delta}$$

$$E_{tx} = energy\ required\ \ for\ transmission\ of\ \ control\ packets$$

$$E_{gen} = energy\ required\ \ for\ \ packet\ \ generation$$

$$d = dis\tan ce\ \ between\ \ nodes$$

$$\delta = attunuatio\,n\ \ factor\ \ 0.1 \le \delta \le 1$$

$$E_{gen} \prec\prec E_{tx}$$

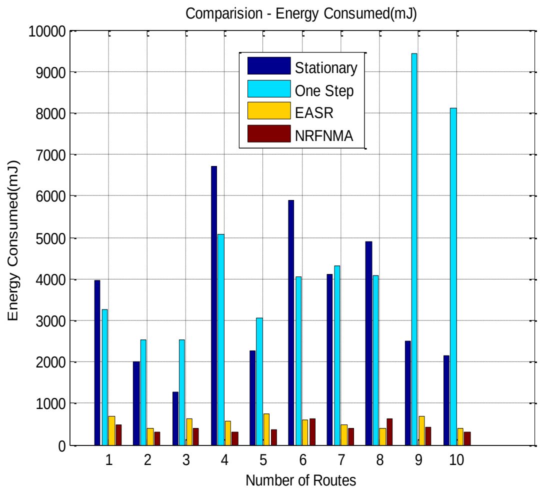

Fig 21:Energy Consumption

Fig 21 shows the energy consumption of routing process. As shown in the fig for iterations 1, 2,3,4,5,7,9 and 10 the proposed NRFNMA algorithm has the lowest energy consumed as compared to other methods. On an average the proposed NRFNMA has the lowest energy consumed followed by EASR, One Step and Stationary algorithm.

D. *Routing Overhead*

The routing overhead is defined as

$$Routing\ \ Overhead = \frac{Number\ \ of\ \ control\ \ packets}{Number\ \ of\ \ Data\ \ packets}$$

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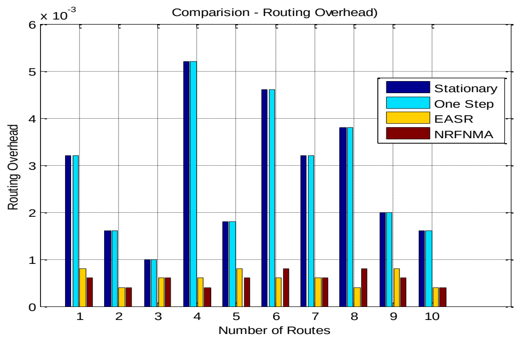

Fig 22:Routing Overhead

Fig 22 shows the Routing Overhead of routing process. As shown in the fig for iterations 1, 2,3,4,5,7,9 and 10 the proposed NRFNMA algorithm has the lowest routing overhead as compared to other methods. On an average the proposed NRFNMA has the lowest routing overhead followed by EASR, One Step and Stationary algorithm. For the iteration1 3.2 *10-3 is the value of routing overhead for stationary and one step algorithm, 0.8*10^-3 for EASR algorithm and finally 0.7*10^-3 has the value of NRFNMA. The lower the routing overhead the better is the working of algorithm. The Number of data packets are 1000.

E. End to End Delay

End to End Delay is the time taken for the RREQ to go from the source node to destination node and then send back the RRPLY from destination node to source node.

$$E2E_{delay} = t_{stop} - t_{start}$$

Where,

$$t_{stop} = \text{This is the Time at which RRPLY is recieved}$$

$$t_{start} = \text{This is the Time at which RREQ is send}$$

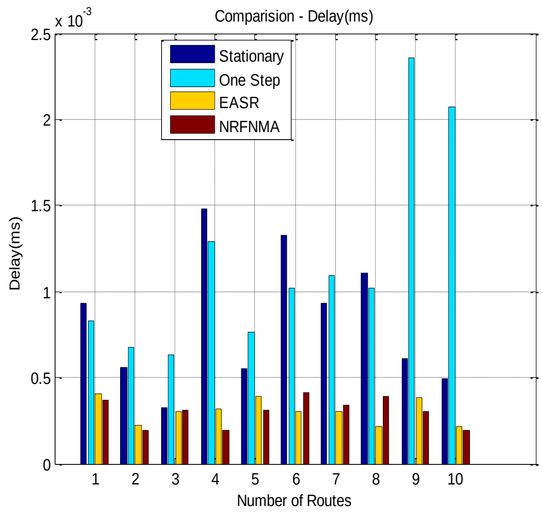

Fig 23: End to End Delay

Fig 23 shows the end to end delay for all the algorithms. As shown in the fig the NRFNMA algorithm has the lowest delay as compared to EASR, One Step and Stationary algorithms. NRFMA algorithm has lowest end to end delay for iterations 1,2,4,5,9,10 as compared to other algorithms.

VIII. CONCLUSION

This work describes the proposed algorithm starting from the network model which involves the placement of node, energy consumption model which describes the energy reduction, network lifetime effects, genetic recovery process which is responsible for recovery of dead nodes periodically, route discovery algorithm which involves the path discovery between the source node and destination node in a better fashion by picking the node with high energy among alive nodes and intermediate node shifting its position if none of the nodes are healthy. There is also the discussion on how the proposed method improves the network lifetime as compared to EASR method with respect to forward node pick and periodic node recovery.

From the Simulation results the proposed method performs better as compared to several existing methods with respect to End to End Delay, Total Energy Consumption, Residual Energy of Network, Number of Dead Nodes, Number of Alive Nodes, Lifetime Ratio and Routing Overhead.

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