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A Relay Mote Wheeze for Energy Saving and Network Longevity Enhancement in WSN

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***Abstract*: Weather Monitoring, surveillance of enemy vehicles, sensed data delivery are few of the applications of Wireless Sensor Networks. All the applications want the nodes to spend their energy in the critical activities. Lifetime depends on the residual energy of the nodes in the network. In this work we modify the Global Energy Balance [1] algorithms to have better network lifetime by making use of fixed relay nodes at various positions in the network. The selection of relay node is based on the distance and residual energy of the relay node all through the route discovery practice. The FRNS scheme is compared with existing algorithms for diverse parameters like End to End Delay, Overall Hops Count, Overall Alive nodes and Dead nodes, Residual energy, Lifetime ratio, Energy Consumption, Throughput and Routing Overhead.**

***Index Terms*: WSN, Energy Redeemable, Network Lifespan.**

I. INTRODUCTION

Wireless sensor network (WSN) [2] are used in the detecting the event occurrence. If the detection can be performed in the distributed manner then energy saving can be performed. Several poisonous gases namely methane and carbon monoxide causes diseases and also can cause explosions. The mining area can be covered using WSN nodes. There are two important entities [3] namely Energy Consumption and Cost of installation. A two stage approach is used in which with minimum cost of installation a user specific lifetime can be achieved and in the second stage can maximize lifetime and also maintain the nodes as in first stage. Maximum-likelihood estimator with quantized [4] data with flavour of Cramér.Rao lower bound (CRLB) and optimal design for the quantized can save communication bandwidth and energy. The data is increasing at an exponential rate, when large quantity of nodes is deployed in the network which handles the superior data there is a lot of redundancy of data among nodes. In order to remove the redundancy energy saving data aggregation [5] based on Modified K means algorithm which can enhance the network lifetime.

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Clustering in WSN Network [6] is responsible for achieving power saving and scaling up. Network delay occurs when energy saving has to be done. Clustering scheme which does a balancing act between delay and energy has been used. There is variety of use cases which has to be taken care in case of data aggregation. Fog computing and the storage of data [7] has been moved towards the nodes which are part of network edge.

Optimization of network is done with the help of total energy usage and node energy usage. The lifetime of the network [8] is directly proportional to the energy efficiency Traffic and Energy Aware [TEAR] improves the stability period. One more approach to improve the energy efficiency [9] in the network is to turn off network nodes and links. The algorithm achieves the balance between energy consumption, network performance and resource utilization. Few Mobile nodes do not deliver packets obtained from other nodes and use its independent nodes for data delivery. E-STAR protocol [10] makes use of reliability and capability to deliver the packets and minimizes possibility of breaking the routes. Simultaneous wireless information and power transfer method [11] provides transmission of information and power the nodes with radio frequency signal. The routing metrics make use of energy consumption of link in order improve the network lifetime. When WSN are used to transmit audio, video link quality estimation [12] is the most important concept for achieving Quality of Service (QoS). The forward node is selected based on link quality, distance and remaining energy. WSN are used to gather information on environment [13] factors like pressure, temperature, humidity. The major challenge is the battery consumption. The drainage of battery at a fast rate is important for energy efficiency. Multi hop communication is better way to achieve energy efficiency [14]. There are lot of holes created because more traffic is diverted towards the sink creates energy holes. A utility function which makes use of energy transmitters and optimal number of energy transmitters is created to improve the lifetime. When the number of nodes increases it causes depletion [15] in the energy levels of nodes rapidly and the nodes die. Energy Aware Sink Relocation is considered as the way to increase energy efficiency and improves network lifetime. Whenever handoff happens mobiles from one area move to another area of hexagonal cells and call remains same but signal gets deteriorate. The clustering and cluster head election using LEACH-ERE [16] will increase the efficiency in network along with lifetime. The number of packets dropped is the main criteria [17] for the nodes to be termed as malicious and the residual energy of the nodes must be monitored to detect hotspots.

The energy consumptions [18] of nodes can be reduced and holes formation can be prevented if mobile sink is used in a delay sensitive applications. The hop distance can be used to assign weights to the sensor nodes and retrieve all the sense data. WSN nodes have limited power resources which have to be conversed in order to prolong the lifespan of WSN network. Energy Proficient Sink Relocation [19] algorithm is proposed which will adjust the communication range based on residual battery energy of the mote and then reposition the sink if all the nodes have lesser energy. The challenges in WSN are limited battery charge [20] and bandwidth. LEEACH randomly selects cluster heads for energy decimation. PEGASIS method makes different cluster heads for different rounds by computing residual energy during different cycles. Shortest Path Tree and Minimum Spanning Tree improve the packet delivery ratio but they suffer from delay, hops as well as complexity. DHSP algorithm [21] discovers the route based on direction of destination node. When the density of the nodes increases the transmission range can be decreased. SHARE [22] algorithm makes use of link state statistics, braid forwarding and flooding approach which can be used to minimize overhead and maximize network scalability. When there are a lot of nodes whose battery level is less then it becomes difficult to recharge power supplies. Adaptive Multi Hop Routing Algorithm (AMRA) [23] can perform balance for the entire network and also reduce energy consumption. A fitness function has parameters like energy depletion, route span and enduring energy to have better routing results.

II. NETWORK FORMULATION

Consider a square area with the core end points Xstart, Xend, Ystart and Yend. The node has three characteristics battery, Memory and Antenna. Nodes must satisfy the boundary limitations Xstart ≥ Xi ≤ Xend and Ystart ≥ Yi ≤ Yend. Xi, Yi are presenting the position of the ith node in the network. Two nodes cannot occupy the same position hence they must satisfy the network model must satisfy the condition (Xq , Yq) ≠ (Xw ,Yw). Xq, Yq Represents the position of qth node and Xw, Yw represents the position of Wth node in the network. Let the total number of nodes be represented as Nn which must exist in order perform the route discovery. The node can be represented by using unique two attributes namely Node Id and respective position of node in the network. The network formation in the simulator is done based on the NDM matrix and placed in the network. The network Formation can be described as given below:

Algorithm1: Network Formation

Input: $N_n, x_{start}, x_{end}, y_{start}, y_{end}$

Output: A set of node information NI

Description:

a) $k = 1$

b) $k : 1 -- > N_n$

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

$x_i = n_v$

any n_v which satifies

$x_{start} \le n_v \le x_{stop}$ and $n_v \ne x_h$

d) Generate an y position of node which satisfies the objective function

$y_i = n_v$

any n_v which satifies and $n_v \ne y_h$

$y_{start} \le n_v \le y_{end}$

Where,

x_h – history of x positions previously assigned

y_h – history of y positions previously assigned

e) Form a tuple in the format

$$(k, (x_k, y_k))$$

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

Node	Position
k	(x_k, y_k)

g) $k = k + 1$

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

Each and every time the above process must 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 fig 1.

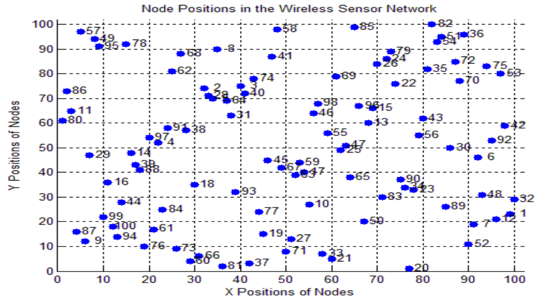

Fig 1: Network Model graph for Iteration1

Fig 1 shows the nodes spread across the given area with the limits defined as $x_{start} = 1, x_{end} = 100, y_{start} = 1$ and $y_{end} = 100$

There are 100 nodes which have been deployed. Each of the nodes has its own node id and position of node in the network which is having the objective function $1 \le x \le 100$ and $1 \le y \le 100$. The two nodes in the network do not have the same position. For instance as revealed in the fig 1 Mote 37 is around 42 y and 4 x from the reference point (1, 1). Node 77 is present at 43 y and 25 x. Hence Node 43 follows the condition specified in the network model $x \ne X_H$ & $y \ne Y_H$.

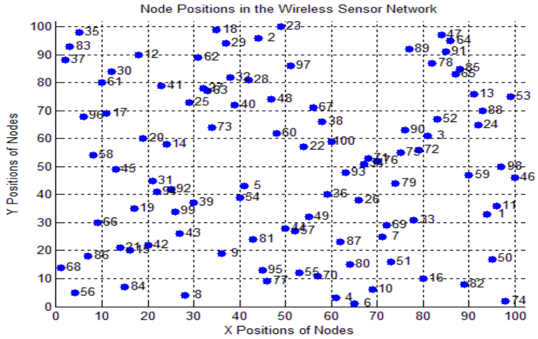

Fig 2: Network Model for Iteration2

The motes in the grid change the position of the motes in the network and fig 2 shows the same for the iteration no 2. Node 37 and Node 77 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
37	(4,42)	(89,2)
77	(25,43)	(45,10)

Table1: Position of Nodes in Network

Table 1 shows the position of motes in the network, namely mote 37 and mote 77 have changed their positions using the same algorithm1 over a period of time.

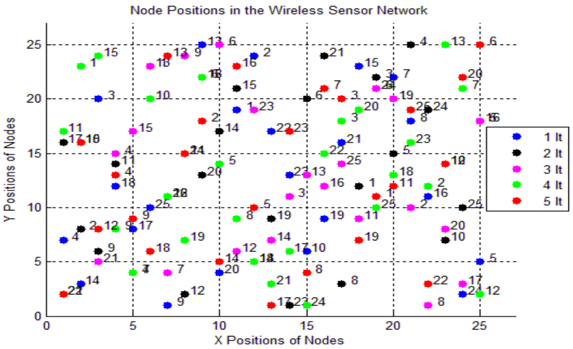

Fig 3: Position Changes of all Nodes

In the network which has a mobile environment nodes will keep on changing the positions after certain period of time. Fig 3 shows the change in the position of nodes for the period of 5 iterations with the number of nodes as 25. Blue represents the position of nodes for iteration 1, Black represents position of nodes for iteration 2, Pink represents position of nodes for iteration 3, Green represents position of nodes for iteration 4 and finally Red represents the position of nodes for iteration 5.

III. ENERGY CONSUMPTION ANALYSIS

The energy consumption occurs due to various reasons and the model can be created with respect to the data present in literature [24-30]. In order to model the energy consumption we need to keep an eye on radio propagation. Consider that there are two nodes n1 and n2 located at a distance d. The number of bits transmitted by the node is given by Nb. Transmitter and amplifier are the main components for the node.

The energy required for transmission of Nb bits is given by the following equation.

$$E_t(N_b, d) = N_b * (E_{tr} + E_{rc} * d^n) \quad (1)$$

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

$$E_{rc} = N_b * E_{tr} \quad (2)$$

The total energy consumed for transmitting data over a distance of d will be computed using the following:

$$E_c = 2 * N_b E_{tr} + N_b * E_{rc} * d^n$$
$$E_c = N_b (2 * E_{tr} + E_{rc} * d^n) \quad (3)$$

Table 2 shows the standard values for energy levels [28]

Type	Energy Consumption
Transmitter energy	50 nJ/bit
Receiver energy	100 pJ bit/m

Table 2: Energy Consumption Standards

The node loses its energy when it is involved in the transmission. Consider the path which has the nodes which participate in routing;

$$1 --> 3 ---> 5 ---> 8$$

Node1 acts like a sender and Node 8 acts like a receiver. Suppose the distance between the nodes 1 and 3 is 40m, number of bits are 100 and n=1. Substituting the standard values from table1 for energy levels and making use of equation1 the following is the energy consumed between Node1 and Node3.

$$E_c = 100\ (2 * 50\,nJ + 40\,pJ * 40\ ) = 1.3600e\text{-}005$$

If the distance between Node3 and Node5 is 50 then the energy consumption can be found as;

$$E_c = 100\ (2 * 50\,nJ + 40\,pJ * 50\ ) = 1.3600e\text{-}005$$

The distance and energy are directly proportional to each other. When the distance increases the energy consumption also increases as shown in the fig4

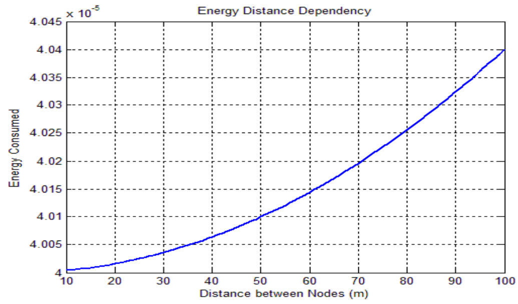

Fig 4: Distance v/s Energy Consumption

As shown in the fig4 as the distance increases the energy consumed also increases. The graph is obtained by varying the distance between 10 to 100 m in increments of 10 m and keeping other values from the standards and substituting in equation1.

IV. LIFETIME RATIO COMPUTATION

Lifetime ratio plays an important role for packets to be propagated in the network. The topology structures like square, linear, triangle and quadrangle topologies have varying definition of network lifetime [29-30]. The lifetime ratio is given by the following equation.

$$LR = Na / N_d \quad (4)$$

The initial value of the battery power is represented by IB. A node is said to be dead which has residual energy less than IB/4. When the mote play a part in routing then the energy reduction happens and the restructured energy can be computed using [31].

$$U_E = C_E - E_C \quad (5)$$

Consider that all the nodes have initially the same amount of energy of 5000mJ.

Node 1 has participated in routing process and distance between Node 1 and Node 3 is considered to be 30m.

$$UE_f = CE_f - E_c = 5000 - 1.3600 = 4998.6$$

If the same node is used for a large amount of data transmission repeatedly and the energy of the node reduces by B/4. In the case of node 1 it is 1250. When the nodes repeatedly participates in routing the residual energy level graph can be obtained as in fig5. It shows the functional dependence of number of times node participates in routing versus the remaining energy for the motes in the network. From the fig5 the residual energy decreases as the amount of times a mote participated in routing upturns. It is evident from the fig that a point will

reach at which the node will become dead.

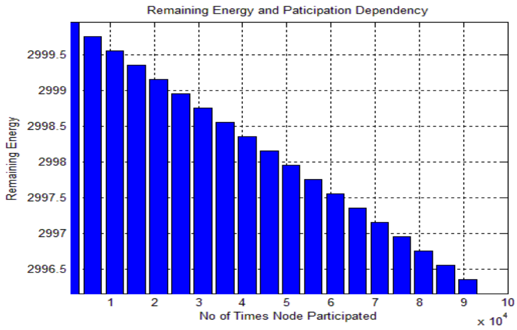

Fig 5: Residual Energy and Participations

V. RELAY NODE

Relay nodes are nodes which have more energy with recharging units and since they are in fixed positions if they lose the energy below the threshold then they can recharge themselves so that the overall network lifetime is increased. The placement of the relay nodes depends on the type of topology under which nodes are operating. Fig 6 shows the placement of the relay motes.

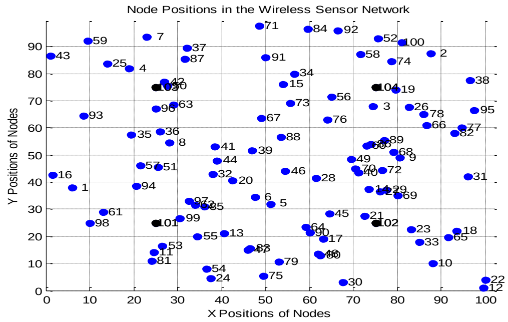

Fig 6: Node Deployment with Relay Nodes

Fig6 shows the node deployment with relay nodes. The relay nodes have been indicated in black color and then other nodes are indicated in blue color. Node 101 is placed at (25, 25), Node 102 has been located at (75, 25), Node 103 has been placed at (25, 78) and Node 104 is placed at (75, 75).

VI. MODIFIED GTEB

The route discovery aims at finding the path with the aim of improving network lifetime and reducing the burden on the nodes with respect to energy consumption by transferring this work to relay nodes whenever they come into picture. If the neighbors nodes does not have relay the route discovery will be done by picking the node which have better energy levels.

The route discovery process can viewed in the algorithm 1 as given below and if the route has the relay node then relay node pick up strategy is narrate in algorithm 2. From algorithm 1 the source node primarily finds the neighbors, if the neighbors contain destination node then stop the routing process otherwise divide the neighbors into 2 sectors. For each sector compute sector continuous function, equilibrium equation, Jacobean matrix, compute the eigen values for Jacobean matrix. Pick the nodes which belong to highest eigen value. Compute the payoff for the sector nodes and then pick node which has the highest payoff. If the nodes in the neighbor set have a relay node then fitness function for each of the neighbor nodes is computed and then a relay node which has highest fitness function is chosen and then same practice is reiterated till end point is reached as given in the algorithm 2.

Algorithm 1: Route Discovery Process

Input: Source mote, destination mote, transmission range

Output: Path between source node to destination node with or without relay node as intermediate nodes.

1. Source and destination node acts as input.
2. Find the neighbour nodes within the transmission range
3. Check whether the neighbour nodes have destination
4. Check whether the neighbour nodes have relay node
5. The region around the SN is divided into two regions
6. Compute the Sector Continuous Function using the following
7. Find the set of nodes belonging to sector S_i as
8. The initiator SN will send the RREQ and then obtain the remaining energy levels of the nodes in the set
9. Find the set of nodes whose energy levels are higher than B/4, B is initial from the set of nodes. as with energy levels
10. 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.
11. Equilibrium computation
12. Jacobian Matrix computation
13. Compute the eigen values form the Jacobian matrix
14. Find the highest eigen value sector
15. Pick the nodes belonging to highest eigen value sector
16. Compute the payoff for each of the nodes
17. Pick the node which has the highest payoff.
18. Repeat the process until destination is reached.

Algorithm 2- Relay Node Path Completion

Input- Initiator Relay Node, Destination Node

Output- Path from initiator relay node to destination node.

1. Relay node will find the neighbor nodes.
2. If the neighbor nodes of the relay has the destination node then stop the route discovery, else step3 will get executed.
3. Pick up only relay nodes from the neighbor set.
4. The next relay node is picked based on distance to destination node and highest residual energy among the neighbor set called a fitness function.
5. Consider the fitness factors for the neighbour relay nodes
6. Find the highest fitness function.
7. Node corresponding to maximum fitness factor becomes the forward node.
8. Repeat process until destination is reached.

VII. OMPARISION ALGORITHMS

The proposed route discovery and relay node algorithms are compared with several existing approaches like Random Routing, Random CGT, Random-EGT Global Energy Balance (GTEB) Routing algorithms.

Algorithm 1: Random Routing

Input: source node, destination node, transmission range

Output: Path between source node to destination node with intermediate node selected randomly and also sector is picked randomly

1. Fetch the Routing table for the source node.
2. The region near to source node is divided into two sectors.
3. Select one of the sector randomly.
4. If the sector motes have end point then halt the process.
5. Pick next forward node randomly.
6. Repeat the process from Step1 to Step6.

In the above algorithm neighbour nodes are found out and then if the neighbour nodes have destination then route discovery is stopped otherwise the node is picked up randomly.

Algorithm 2: Random CGT

Input: Source node, destination node, transmission range

Output: Path between source node to destination node with sector selected randomly and sector selected based on highest eigen value

1. Fetch the Routing table for the source node.
2. The region near to source node is divided into two sectors.
3. Pick the sector randomly.
4. Once sector is selected then payoff is computed for the nodes.
5. If the motes have end point then halt the progression or else step6 is executed.
6. Find the payoff for the nodes.
7. Pick the node which has the highest payoff.
8. Repeat the process until destination is reached.

In the above algorithm source mote, destination mote, communication range will act as an input, neighbor nodes are divided into sectors, pick the sector randomly, once a sector is selected payoff for the nodes is computed and then node which has the highest payoff is chosen as the next forward node. Repeat the process until destination node is reached.

Algorithm 3: Random -EGT

Input: Source node, destination node, transmission range

Output: Path between source node to destination node with intermediate node selected randomly with good sector

1. Fetch the Routing table for the source node.
2. The region near to source node is divided into two sectors.
3. Compute the Sector Continuous Function.
4. Equilibrium computation.
5. Jacobean Matrix computation.
6. Compute the eigen values form the Jacobean matrix.
7. Find the highest eigen value sector.
8. Pick that corresponding sector to find the nodes.
9. If the motes have end point then halt the progression or else step10 is executed.
10. Find a forward node randomly.
11. Repeat process until destination is reached.
12. Compute the Sector Continuous Function using the following.

In the above algorithm source mote, destination mote and communication range will act as an input. Find the neighbour nodes, if the source node has destination node then stop routing otherwise compute sector continuous function, equilibrium, Jacobean matrix then find the Eigen values and pick the sector which has maximum Eigen value. Pick the random node among the neighbour nodes.

Algorithm 4: GTEB

Input: Source node, destination node, transmission range

Output: Path between source node to destination node with intermediate node based on payoff

1. Source node and destination node acts as input
2. Find the neighbour nodes within the transmission range.
3. Check whether the neighbour nodes have destination.
4. The region around the SN is divided into two regions.
5. Compute the Sector Continuous Function
6. Find the set of nodes belonging to sector S_i
7. The initiator SN will send the RREQ and then obtain the remaining energy levels of the nodes in the set.
8. Find the set of nodes whose energy levels are higher than B/4, B is the initial energy from the set of nodes. as with energy levels
9. 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.
10. Compute the equilibrium equation
11. Compute the Jacobian Matrix using the following equation
12. Compute the eigen values form the Jacobean matrix
13. Find the highest eigen value sector
14. Pick the nodes belonging to highest eigen value sector
15. Compute the payoff for each of the nodes
16. Pick the node which has the highest payoff
17. Repeat the process until destination is reached

In the above algorithm source mote, destination mote and communication range will act as an input. Find the neighbor nodes, if the source node has destination node then stop routing otherwise compute sector continuous function, equilibrium, Jacobean matrix, find the eigen values, pick the sector which has maximum eigen value, find the payoff values for neighbor nodes and then pick node which has highest payoff and repeat the process until destination is reached.

VIII. RESULTS AND ANALYSIS

This fragment provides the results of route discovery for propound method and also related with GTEB, Random-EGT, Random-CGT and Random Routing algorithm. The experimental set up assumes the following input parameters;

Parameter	Parameter Assessment
Number of Nodes	104
Transmission Range	40 m
Transmission Energy	20 mJ

Generation Energy	10 mJ
Topology	Random
Number of iterations	25
Attenuation Factor	0.7

Table 3: Input Parameters

The above table indicates the input parameters used in the MATLAB simulation. The proposed algorithm has been compared with several existing methods namely Random routing, Random-EGT, Random-CGT and GTEB for various network parameters.

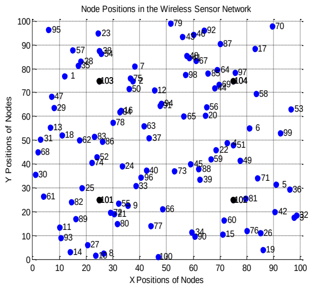

Fig 7: Mote Deployment Algorithm

Fig 7 shows the position of motes in the network. From the fig7 there are 104 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. The relay nodes namely Node 101 is placed at (24, 28), Node 102 is placed at (77, 28), Node 103 is placed at (25, 75) and Node 104 is placed at (75, 75).

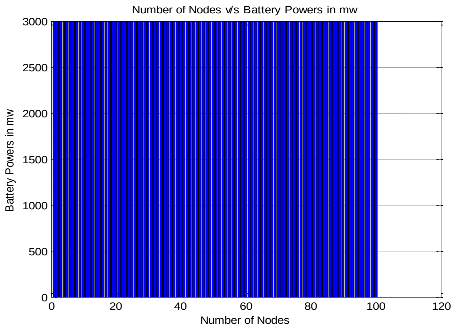

Fig 8: Battery Power of Nodes in the Network

Fig 8 shows that all the 104 nodes have been initialized with the same amount of energy of 3000mJ.

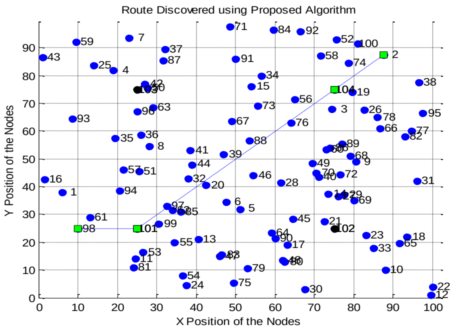

Fig 9: Route Discovery using Proposed Method

Fig 9 shows the route discovery using proposed method. The route is revealed among source mote 98 and destination mote 2. The communication route discovered has the following path.

Node 98→ Node 101→Node 104→ Node2

A. End to End Delay

End to End Delay is the amount of interval engaged for the RREQ to drive from the source mote to destination mote and then drive return the RRPLY from destination mote to source mote.

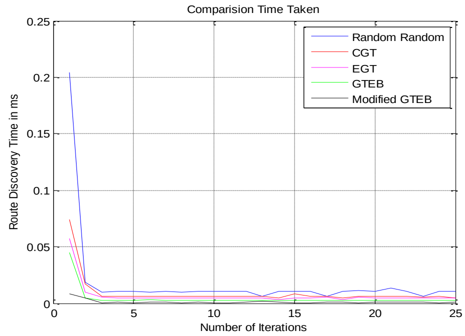

Fig 10: End to End Delay

Fig 10 confirms modified GTEB has the lowest delay which is around 0.01ms or lesser as compared to GTEB, EGT, CGT and Random. The GTEB delay ranges from a maximum of 0.05ms to 0.02ms. EGT has the delay in the range of 0.06ms to 0.03ms. CGT has the delay in the range of 0.09ms to 0.04ms. Random has the highest end to delay of 0.2ms to around 0.045ms.

B. Number of Hops

Fig 11 confirmations the total number of intermediate hops. As shown in the fig11 Modified GTEB has the lowest number of hops around 10 hops or less across the iterations. GTEB has the next lowest number of hops which are around 8 hops or less. EGT has hops which varies in the range of 25 to 24 hops. CGT has the hops which vary between the ranges of 35 to 32 hops. Random has the highest number of hops due to back and forth propagation the route.

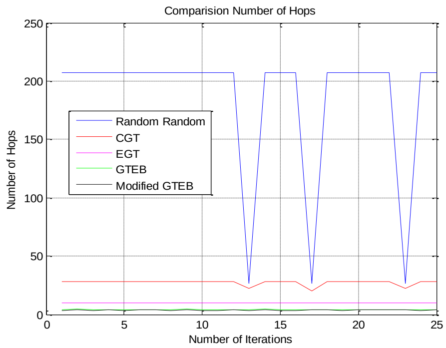

Fig 11: Number of Hops

C. Total Energy Consumed

The overall energy depletion is specified as trails;

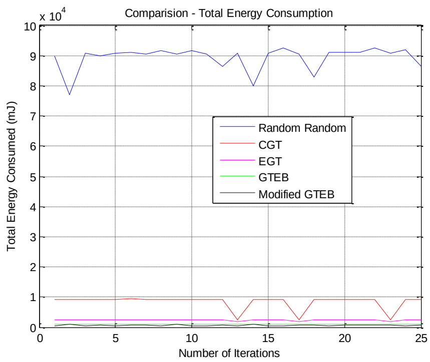

Fig 12: Total Energy Depletion

Fig 12 confirmations the overall energy depletion assessment. As shown in the fig12 the modified GTEB has the lowest energy consumption followed by GTEB, EGT, CGT and Randomized algorithm.

D.Number of Alive Nodes

This is demarcated as the reckoning of set of motes whose battery extent is grander than or else identical to B/4 Where B is preliminary battery potential. Fig 13 confirmations the total amount of alive motes in the network. As revealed in the fig13 the total number of alive nodes for Modified GTEB algorithm followed by GTEB, EGT, CGT and Randomized algorithm. Modified GTEB has all 104 nodes are alive, GTEB has 103 nodes as alive, EGT has 98 nodes as alive, CGT has 89 nodes as alive and randomized algorithm has 82 nodes as alive at the end of 25 iterations.

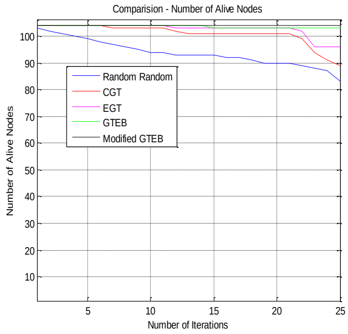

Fig 13: Number of Alive Nodes

A. Lifetime Ratio

Fig 14 confirmations the lifetime ratio assessment as revealed in the fig14 the modified GTEB has the highest lifetime ratio followed by GTEB, EGT, CGT and last is Randomized algorithm. Lifetime ratio is measured based on highest measure of motes because maximum nodes are 104.

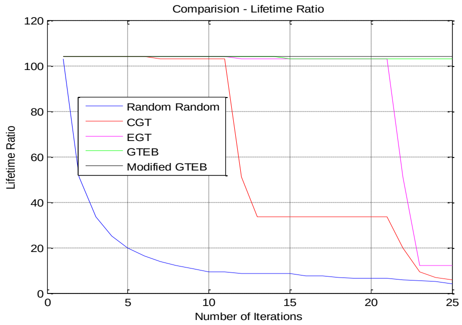

Fig 14: Lifetime ratio comparison

B. Routing Overhead

Fig 15 confirmations the Routing Overhead of routing process. As shown in the fig15 Modified GTEB has the lowest routing overhead followed by GTEB, EGT, CGT and Randomized algorithm. The routing overhead is demarcated by way of

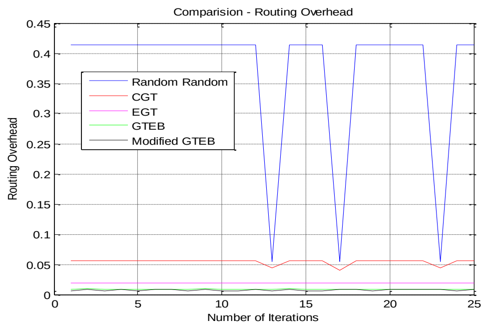

Fig 15: Routing Overhead

C. Throughput

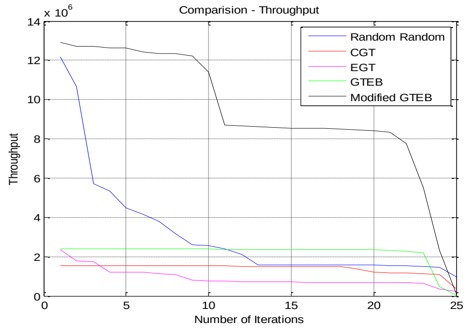

Fig 16: Throughput Comparison

Fig 16 shows the throughput comparison as shown in the fig the Modified GTEB has the highest throughput followed by GTEB, EGT, and CGT and last is Randomized algorithm. During the initial stages 13 MB, followed by Random, GTEB, EGT and CGT.

CESSATION

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, route discovery algorithm which involves the path discovery between the source mote and destination mote in a better fashion by picking the node based on payoff or a relay node with high energy and closer to destination node. There is also description of comparison algorithms which have been picked up. The proposed method overcomes the disadvantages of existing methods like

1. There is lot of back and forth propagation in the routing process for several existing approaches namely Random-CGT and Random-EGT.
2. The other approaches improve the delay constraints and energy consumption using GTEB which decreases Network Lifetime.

From the Simulation knock-on effect the proposed method accomplishes better as compared to several existing methods with respect to End to End Delay, Number of Hops, Total Energy Consumption, Number of Alive Nodes, Lifetime Ratio, Throughput and Routing Overhead.

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