OPTIMIZED ENERGY EFFICIENT CLUSTERING AND ROUTING MECHANISM FOR TARGET TRACKING IN WSN

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Abstract: *Wireless Sensor Network plays a vital role in tracking the mobility of the target like animals habitat monitoring, vehicle monitoring etc. Many researches have been carried out for the precise identity of the target. In this research work, a distributed energy optimization method for target tracking is performed. The proposed work is comprised of estimation phase and prediction phase. Here, clustering is performed using maximum entropy clustering method. Grid exclusion is used for coverage of the nodes whereas Dijkstra algorithm for energy terminologies. Performance evaluation is carried out for the proposed target tracking method with the existing systems using network simulator software.*

Keywords: *WSN, Target Tracking, Maximum Entropy, PSO*

I. Introduction

Due to advancement in technologies, sensor nodes are used in various field for the purpose of physical data monitoring system. The applications include environmental monitoring [1], intrusion detection [2] [3], health monitoring [4], target tracking [5] [6]. Recently these sensors are used not only for the physical monitoring and also to track an object in a particular area [5] [6]. The author [7] focused on target tracking on moving objects with obstacles. The prime cause of the energy consumption in tracking the target is that to identify the energy efficient path for transferring the sensed data. Since it affects the overall network lifetime In this [8], the author has proposed three step localization based approach for target tracking of non line of sight object effect. Bayesian sequential test is used to predict whether the data is being affected by this effect and Modified Kalman Filter (MKF) is used for mitigation [8].

In [9], the author focused on handling uncertainties in target tracking. Body of evidence is used for estimating the weight of each sensor. Energy efficient target monitoring system is a challenging issue in the recent research. Clustering is one of the method for efficient target tracking. Initialize, create, update, increment the clusters, retain and monitor the events through online [9] for motion pattern of target. In this proposed work, an efficient target tracking is performed based on velocity, acceleration and angle of movement by identifying the energy efficient shortest path.

The rest of the paper is organized as follows: related work and methods and materials in section II and III respectively. Results and discussions in section IV. Conclusion and future enhancement is described in section V.

II. Related Work

In this section, various energy optimized target tracking mechanisms can be discussed. The sensor nodes are clustered by maximum entropy clustering [11]. Then, the sensing field is divided for parallel sensor deployment optimization. Energy metrics and radio range are considered for cluster formation. Grid exclusion algorithm is used for coverage related parameters where as Dijkstra algorithm for energy [11]. Various researches have been carried out for efficient target tracking. Some of the research and its working model are described in the following topics.

Target Tracking and Sensor Deployment Model

The author [11] has considered the initial assumptions before constructing the WSN. Both static and mobile sensor nodes are considered to develop WSN for target tracking scenario. Sensing period T is considered for tracking the target. Position of the target node is then and there tracked by the sensor node and reported to the sink node [12,13]. The node is equipped with GPS system for continuous location tracking. Predefined location is used for the deployment of the static nodes whereas dynamic node are allowed to move in order to track. Coverage of the sensor node [11] is explained as follows.

Node coverage

In this probability detection model is used for reliable detection. All sensor nodes in the sensing range will detect the target sensor node having better reliability of detection by considering the factor of electromagnetism and white noises in real situations [11].

Probability Coverage Model is a sensor detection model. This ensures the reliable detection probability. If all sensor nodes having sensing range *rs* then according to concept of probability coverage model, the coordinates of the sensor node *1* be (x_1, y_1) whereas the coordinate of the target node can be given as (x_T, y_T). The possibility of detecting the target RD by the sensor node 1 is given as follows:

$$RD_1 = \begin{cases} 0 \ \text{for} \ \frac{\text{dt,1}}{\text{rs}} \geq 1+\delta \\ \text{Exp}\left(-\frac{\lambda 1 \alpha 1 \beta 1}{\alpha 2 \beta 2}\right) * \lambda 2 \ \text{for} \\ (1-\delta) < dt, 1/\text{rs} < (1+\delta) \\ \lambda 2 \ \text{for} \ \text{dt}, 1/\text{rs} \leq (1-\delta) \end{cases} \tag{1}$$

where, the parameter (dt,1) is the distance between the sensor node 1 and the target. Let us consider the uncertainty of target detection as δ, the probability detection constants as λ_1, $\lambda 2$, β_1 and β_2. Hence,

$$\alpha_1 = rs.(\delta-1) + dt,1$$

$$\alpha_2 = rs.(\delta+1) - dt,1 \tag{2}$$

with the above equations, reliable detection probability of target node can be identified. According to highest reliable probability sensor node *i* will communicate to the target node.

In target tracking, vehicle target are moving randomly with maximum speed and acceleration. The node nearer the target node communicates with the sensor nodes within its sensing range for predicting the node for communication based on reliable detection probability. Bearing angle between the target node and the selected node is predicted [11].

Let us consider that the target is located at (X_t, Y_t) which is predicted by M number of sensor nodes in the network where the least value say M>2. Location of *j* number of sensor node as (X_j, Y_j) which creates an angle as:

$$\theta_j = \arctan [(Y_j - Y_t) / (X_j - X_t)] + \xi_j \tag{3}$$

where, ξ_j – Direction finding error

Estimation on Energy Consumption

Each sensor node is meant for sensing, processing and communication. The communication or radio range is of two categories: low power listening and receiver to transmitter ratio. Former consumes less power compared to the later one. Each sensor defines five states i.e. S0, S1, S2, S3, S4. Sensor node consists of following: Sensing component, five states of each sensor node during target tracking is given in Table 1. From this table, it can be observed that S_4 having low energy consumption whereas S_0 can be awakened hence memory is active and sensor and processor component get ON and radio component set to $R_x \backslash T_x$ mode hence state S_0 having maximum power consumption.

Table 1
Stages of each sensor node in target tracking

Sleep state	Strong ARM	Memory	Sensor and A to D Convertor	Radio
S0	Active	Active	On	T_X, R_X
S1	Idle	Sleep	On	R_X
S2	Sleep	Sleep	On	R_X
S3	Sleep	Sleep	On	Off
S4	Sleep	Sleep	Off	Off

Node Deployment

In WSN, addition and deletion of nodes are common as they are prone to die due to lack of energy [11]. Energy optimization has to be performed to analyze the energy consumption. Clustering mechanism helps to balance the energy consumption as it avoids the raw data communication and longer distance communication. Grid based clustering mechanism is done to perform effective clustering and topology formation. Also clustering best suits for coverage problem as the node communicates only to the node in its radio range. Energy efficient shortest path is predicted to transfer the data towards the destination.

Coverage Metric

The reliable target tracking detection possible area is considered for the network analysis. In clustering, the mobile sensor node is considered as a cluster head whereas the rest of the nodes act as stationary nodes for optimization. Initial node coverage stage is computed using grid exclusion algorithm. Possible detection of the target is estimated. Each cluster is responsible for predicting the reliable detection estimation and coverage. It helps to detect the target in unreliable detection area also.

III. Methods and Materials

Proposed Modified Shortest Path Algorithm for Routing in setup phase

Here, few modifications have been incorporated in the existing algorithm described in the above section for the shortest path routing construction in wireless sensor network. Modifications implemented in the existing algorithm are as follows:

While constructing the shortest path, the path between any two nodes has another similar path of same weight in the reverse direction, between the same two nodes. When there is no ACK/reverse path is available between the nodes, which indicates that there is no direct path available between the nodes. If the weight of the path and the reverse path are not similar which indicates that the corresponding paths are not valid one.

Each node in the WSN has tags, router and coordinator. Algorithm helps to predict the shortest path between any two nodes in the network at any time t which indicates that any node can act as a active/ coordinator node in the network based on the application. This implies that at any instant of time any node can act as a coordinator to predict the shortest path.

If any router node fails to ACK the receipt of the data, the sender assumes that the corresponding recipient is not available. This may because of RF interference or obstacles between the nodes. WSN is designed in such a way that there should be a separate path for the ACK. Routing of sensed data will be affected if the receiver is not able to receive the data.

The proposed method of predicting the shortest path will be shorter than that of the existing algorithm. ACK is taken into consideration in the proposed method. If ACK is not received by the sender, it is assumed that the path is infinite or invalid in the proposed method. Proposed method suits well in shortest path finding and shows improved performance compared to with the result of Dijkstra's Shortest Path Algorithm or any other known shortest path algorithm, then similar result is achieved. The modified algorithm is stated below:

Pesudo code of the proposed method

1. *Enter the input graph, number of vertices n and edges as parameters in a function, say modified_algo(p[][], n).*
2. *Repeat loop for i, j=1,2,.....,n:[Initializes q]. If p[i,j]=0, then set q[i,j]=INFINITY[say, 999], else set q[i,j]=p[i,j]*
3. *[End of loop].*
4. *Repeat loop fori, j=1,2,.....,n.*
5. *If q[i,j]=999 or q[j,i]=999, then set q[i,j]=q[j,i]=999.[Validating a path in condition of presence of its corresponding acknowledgement path].*
6. *If q[i,j] and q[j,i] are not equal, then set q[i,j]=q[j,i]=999.[Validating a path if its length equals that of reply path].*
7. *[End of loop].*
8. *Repeat Steps 5 and 6for k=1,2,.........,n[Updates q].*

5. Repeat Step 6for i=1,2,.....,n.

6. Repeat nested loop for j=1,2,.......,n. Set q[i,j]=min(q[i,j], q[i,k]+q[k,j]).

[End of loop].

[End of Step 5 loop].

[End of Step 4 loop].

7. Repeat loop for i=1,2,.....,n.

Set q[i,i]=0. [No self-loops can be present].
[End of loop].

8. Print the final matrix q of shortest path from every node to node.

9. Exit.

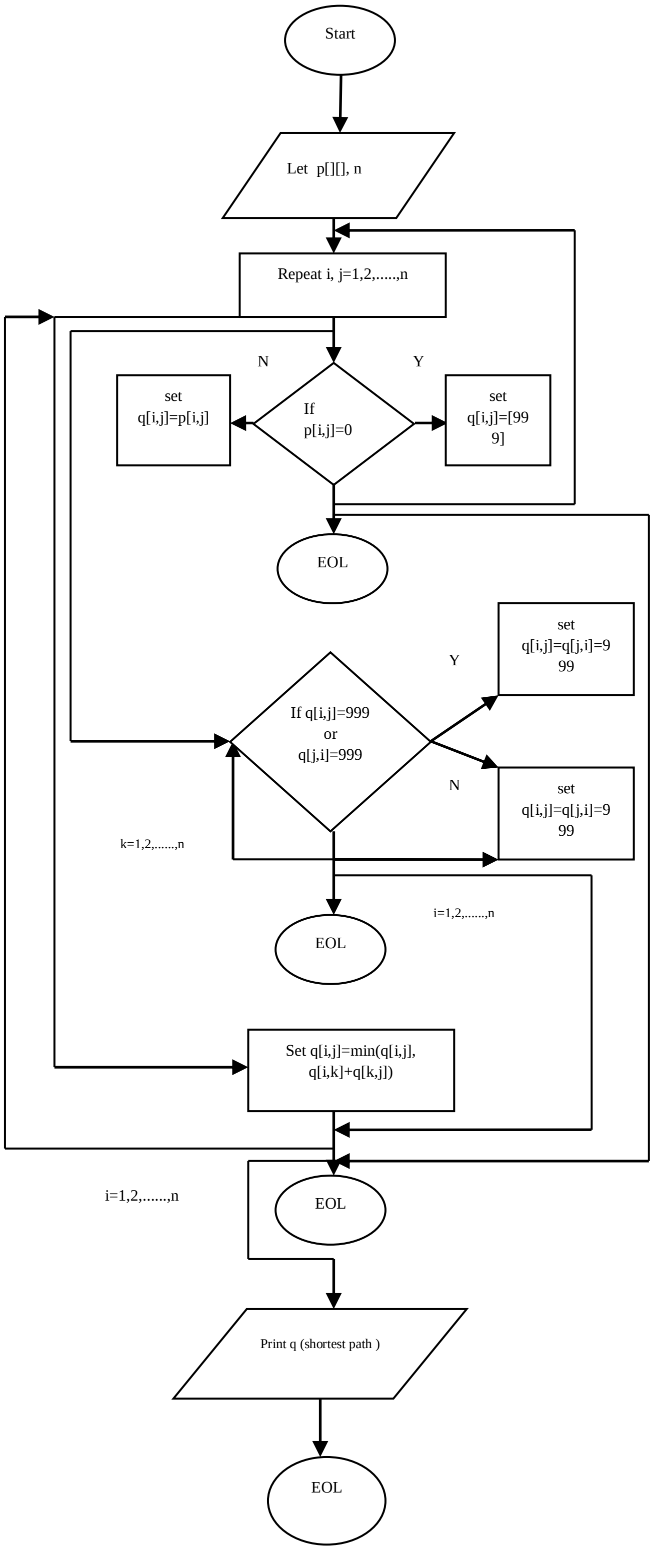

Fig.1 Flowchart of the Modified Shortest path Algorithm

Proposed On-Demand Routing for Sensor Activation Using Genetic Algorithm

Genetic Algorithm

1. Initialize the population
2. calculate the fitness value for each individual of the population
3. do
4. select the best fitness value for reproduction
5. perform cross over for producing better offsprings
6. predict the fitness value for every offspring
7. Replace worst by best offspring
8. end

Genetic algorithm optimization performs the following step to get the best path.

Encoding

Path encoding scheme is used to encode the identified path as 0 and 1 which is an initial chromosomes.

Consider an example.

Identified paths are

1-3-5-6 => 110101
1-2-4-6 => 111000
1-3-4-6 => 101101

The number of bits in the chromosome represents the number of nodes in the network.

Fitness Evaluation

Fitness value is the set of parameters considered as an objective to be attained. In the proposed system, weight of the node link, bandwidth and data transmission delay are incorporated.

Selection

The chromosomes are elected based on the fitness value obtained. And the process is repeated for n number of iterations.

New Population Generation

Crossover

Crossover and mutation is performed to generate the new population. Two chromosomes are selected to perform crossover. Based on the crossover rate the bits are exchanged between them which produces the new offsprings.

For example

Let the chromosomes 110101, 111000 are allowed for crossover. If the first and last two bits are swapped the resultant will be 010111, 001011.

Mutation

Here individual bits are considered and mutated as 0 to 1 or 1 to 0 based on the mutation rate.

For example

110101=>010111

111000 =>001011

Iteration

The same process is repeated for obtaining new chromosomes based on the fitness value. With the specified number of iterations, the best.

Decoding

Once the chromosomes are finalized, decoding is performed which is the reverse process of the first step carried out say as, if the finalized chromosome is 110101 then it is then decoded as 1-3-5-6. This is the predicted best shortest path for the data transmission.

Proposed Localization operation

Static and dynamic sensor node are considered in the networking scenario. Binary sensor model is used for network operation. It predicts whether a sensor node can able to detect the target or not. Ant Colony algorithm is used to predict the position of the target and tracking is performed. Initially current position of the target is estimated. Target's next position is estimated with the help of current and the previous positions of the target. New set of locations are computed and making the mobile sensor nodes to move to that location in order to track the target. Sensor coverage model and energy model are the same used in the proposed method which have been described in the previous section of existing method on node coverage and estimation on energy consumption respectively.

Clustering in WSN

In the proposed system, both the static and dynamic nodes have been considered. Clustering is done individually for static as well as dynamic nodes. For each node, energy of the node, distance to the sink node and reachable neighbor within its radio range is predicted. These three parameters are considered as a weight of the node and is normalized to 0 to 1. The node with maximum weight is considered as a cluster head in that particular iteration. Forming the cluster with in the radio range of the elected cluster head. From the rest of the nodes, the node with next higher weight is elected as a next cluster head. The same process is repeated for the rest of the nodes to form as a cluster.

Pseudo code for clustering

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1. *Predict the centroid for static and dynamic nodes*
2. *Estimation of Φ value*
3. *MEC algorithm is applied for coverage*
4. *Estimate the objective function J for both static and dymanic node*
5. *Deployment of mobile sensor nodes*
6. *End*

Predict the centroid for static and dynamic nodes

Clustering is performed individually for the static and dynamic nodes. Centroid is predicted for the nodes in order to form clusters.

Estimation of Φ value

Maximum entropy clustering (MEC) is used for clustering, as it increases the selectivity by decreases the uncertainty. Initially it is assumed that the sensor nodes are divided into C number of clusters. The number of clusters in the network is determined by the size of the network and data being compressed. Let us consider the coordinate of the centroid as (x_i,y_i) where j= 1,2,..c. each sensor node membership is given by $\mathbf{\Phi = \{ \Phi_{jm}\}_{cxn}}$**,** where Φ_{jm} indicates the grade of membership in j^{th} cluster, m^{th} node. It is necessary to attain the following condition for maximum entropy as follows.

$$\Phi_{jm} \in [0,1],\ 1 \le j \le c;\ 1 \le m \le n \quad (4)$$

$$\sum_{j=1}^{c} \Phi_{jm} = 1;\ 1 \le m \le n; \quad (5)$$

$$0 < \sum_{m=1}^{n} \Phi_{jm} < 1 \quad (6)$$

MEC can be given as:

$$J = \sum_{j=1}^{C}\sum_{m=1}^{n} \Phi_{jm}(d_{j,m}^{v})^2 + \gamma \sum_{j=1}^{C}\sum_{m=1}^{n} \Phi_{jm} \ln \Phi_{jm} \quad (7)$$

Where $(d_{j,m}^{v})^2$ is the euclidean distance between the centroid of the cluster and the sensor node. Since WSN is prone to node failure due to lack of energy, WGSS (within group some of square error) is predicted to reduce the error. The first term in the Equ. 7 indicates WGSS where as the second term indicates the entropy. Initializing the network setup, the number of cluster can be set is as c and threshold value for coverage can be considered as ϵ. The membership matrix Φ can be initiated. Based on Lagrange multiplication, the centroid coordinate can be given as:

$$x_i = \frac{\sum_{m=1}^{n} \Phi_{\mathrm{jm}} \mathrm{x_m}}{\sum_{m=1}^{n} \Phi_{\mathrm{jm}}} \; ; \; y_i = \frac{\sum_{m=1}^{n} \Phi_{\mathrm{jm}} \mathrm{y_m}}{\sum_{m=1}^{n} \Phi_{\mathrm{jm}}} \text{ where j= 1,2,..c} \quad (8)$$

The updated Φ can be given as:

$$\Phi_{\mathrm{jm}} = \frac{e^{-(\mathrm{d_{j,m}^{\gamma}})^2/\gamma}}{\sum_{l=1}^{c} e^{-(\mathrm{d_{j,m}^{\gamma}})^2/\gamma}}; \text{ j= 1,2,..c; m=1,2,..n} \quad (9)$$

Based on the membership matrix the sensor nodes are clustered. The entire sensing region is divided into c clusters and grids. The members of each grid will be determined by the shortest distance with reference to the centroid. And Φ value is predicted for newer mobile nodes in the network.

Particle Swarm Optimization

For energy efficiency, Particle Swarm Optimization (PSO) is used for coverage. PSO is a tool which provides solution for combinatorial and dynamic problems [11]. PSO applied in the proposed system as follows:

Algorithm

1. *Initialize the nodes position and velocity*
2. *Evaluate the energy metrics*
3. *Compute random position and speed*
4. *Repeat 3 with the previous values until maximum metric attained*
5. *Fix final position as location of mobile nodes*
6. *end*

The energy metric objective function for the position *z* is given by:

$$f_l(z) = (c^h)^{\alpha-1}(E^h)^{\alpha} \quad (10)$$

Whereas C represents coverage of the senor node from centroid and E represents energy of the node. α is a balanced coefficient for optimization.

Parameter updation information

1. *Node 1 (x,y) says hello msg*
2. *RX nbr update TX position (x,y) and distance(d), time in the table.*
3. *Perform localization for all nodes to update the same in its own table using prev(x,y), cur(x,y)*
4. *Compute angle and d*
5. *Non localized nodes are identified based on last hello msg time and allowed to perform localization*
6. *Avg speed is estimated with distance and time of data received*
7. *Distance and avg angle is then estimated*
8. *With ref to the avg values, exact (x,y) for each node is predicted for next iteration*
9. *Each computed located is updated in location table*
10. *Each node broadcast nbr distance obtained through hello msg*
11. *nbr id and location is minted by RX as 2 hop nbr list*
12. *initialize the iteration*
13. *node sends own location in iteration 1*
14. *nbr node stores 1 hop nbr location*
15. *nbr location will be sent in iteration 2*
16. *RX maintains 2 hop nbr list & entire network is divided into various sub networks*
17. *Localization is applied till the simulation end*

Target Tracking

After the node deployment, clustering formation and predicting the location, speed, velocity and angle, it is necessary to keep tracking the target. The speed of the target can be estimated as:

$$X^{tar}(t+1) = F X^{tar}(t) + G_1 U^{tar}(t) + G_2 V^{tar}(t) \quad (11)$$

where t indicates the time, X^{tar} is the state vector related to position and velocity. U is the acceleration and V is the noise usually AWGN with zero mean is considered. F is the state transition matrix , G_1 and G_2 are coupling input and noise transition matrix respectively.

$$F = \begin{pmatrix} 1 & T & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & T \\ 0 & 0 & 0 & 1 \end{pmatrix}, G_1 = G_2 = \begin{pmatrix} T^2/2 & 0 \\ T & 0 \\ 0 & T^2/2 \\ 0 & T \end{pmatrix} \quad (12)$$

Target tracking model

1. *X is computed as speed of the target.*
2. *U is computed as ratio of acceleration and speed.*
3. *V is maximum speed*
4. *F, G, G1 matrix is formulated as given in Equ. 12*
5. *F and X are multipled and store in V1*
6. *G1 and U is multipled and store in V2*
7. *G2 and V is multipled and store in V3*
8. *Sum of V1,V2,V3 is stored in X_tar for next iteration speed of target*
9. *Actual angle and predicted angle difference is stored in Y*
10. *Actual speed and predicted speed difference is stored in V0*
11. *X0 and C0 matrix is filled position*

difference and angle difference in each axis.

12. C0 and X0 are multiplied and difference of multiplied value and Y is calculated

13. Result matrix is transformed and sum of actual and transformed matrix is calculated with minimum value.

14. Variance value is divided by (C0 and Transformed C0 are multipled)

*15. Final location of target is identified by Z_tar = covarance * X + gaussian noise*

IV. Results and Discussions

The proposed work on target tracking is a modified work of the existing system described in section III. The proposed system mainly focused on energy efficient optimized path construction to transfer the sensed data to the cluster head and the sink node. Various optimization have been involved in terms of node initialization, genetic algorithm based node formation, maximum entropy based clustering, PSO based network coverage and target tracking has been done based on position, velocity, acceleration and angle of direction. With these effectiveness the proposed algorithm works a step better comparatively with the existing work. Some of the comparative study given below the performance of the proposed than the existing.

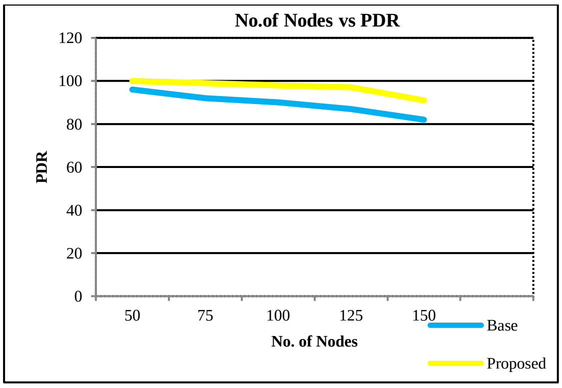

Fig. 2 Comparison on No. of Nodes vs PDR

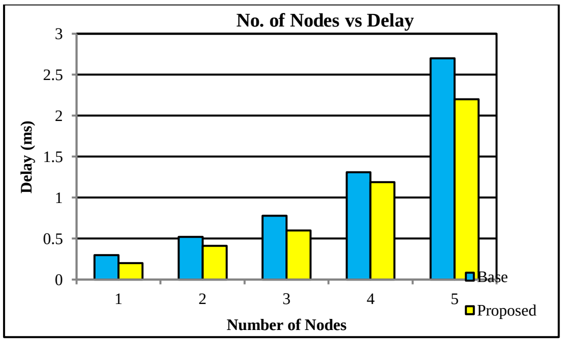

Fig. 3 Comparison on No. of Nodes vs Delay

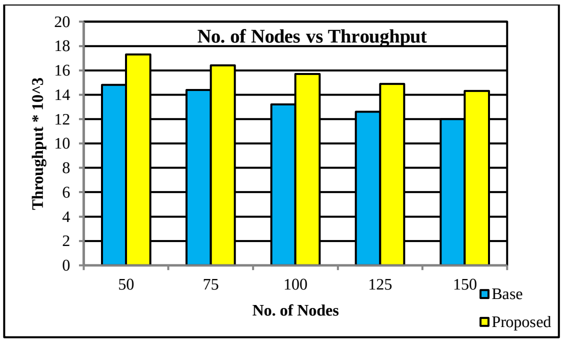

Fig. 4 Comparison on No. of Nodes vs Delay

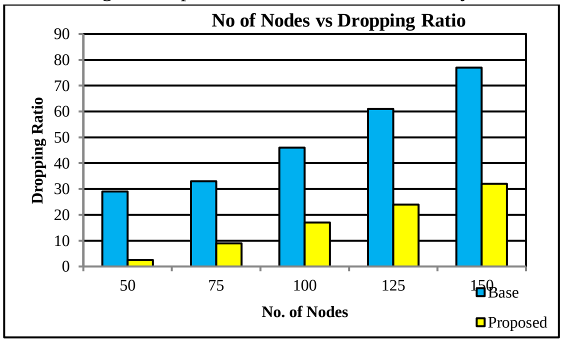

Fig. 5 Comparison on No. of Nodes vs Dropping ratio

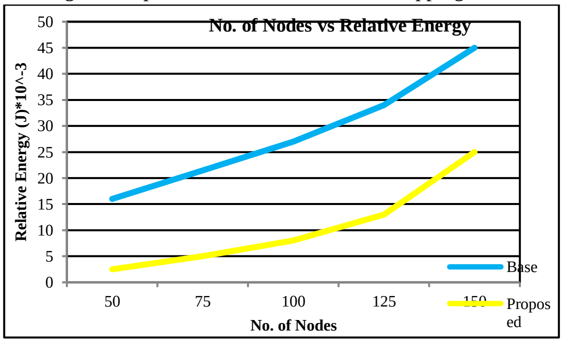

Fig. 6 Comparison on No. of Nodes vs Relative Energy

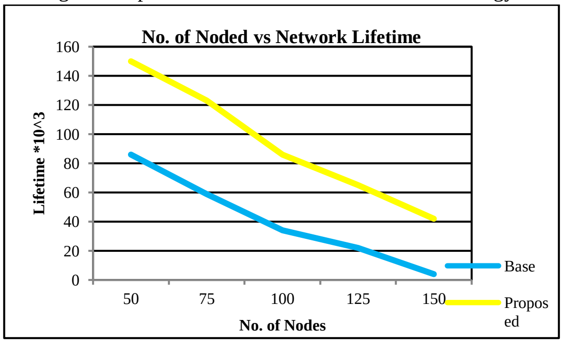

Fig. 7 Comparison on No. of Nodes vs Network lifetime

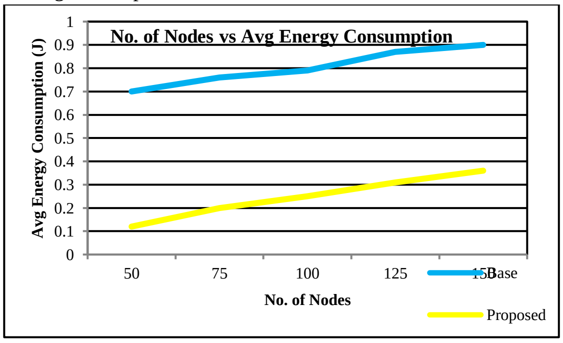

Fig. 8 Comparison on No. of Nodes vs Avg Eng. Consumption

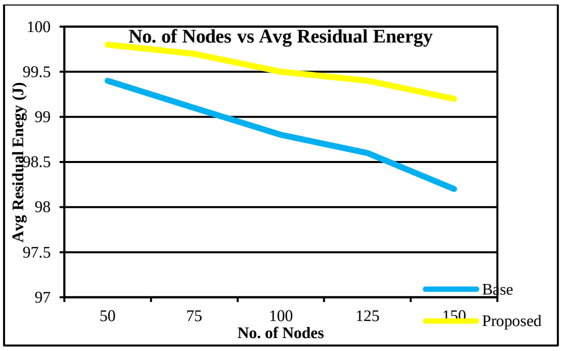

Fig. 9 Comparison on No. of Nodes vs Avg Residual Energy

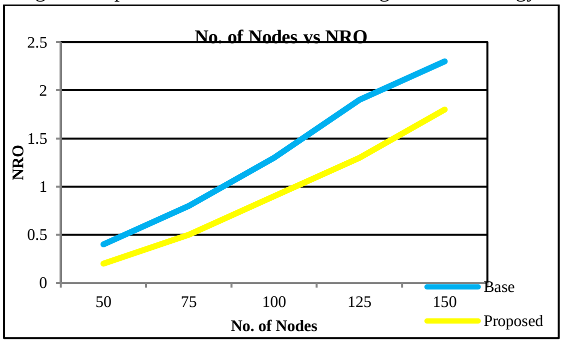

Fig. 10 Comparison on No. of Nodes vs NRO

From Fig 2 and 3, it can be seen that the proposed shows better performance in terms of PDR with less delay in delivering the data to the destination respectively. This is due to the best shortest path predicted in the proposed mechanism. As the number of packets delivered increases results in better throughput which is given in Fig. 4. Dropping of data is inevitable in the network transmission. Lower the dropping rate better the performance. Figure 5 shows the dropping rate between the base work and the proposed system. Dropping rate is comparatively less in the proposed system than the existing one.

Figure 6,7,8,9 deals with the energy and network lifetime. Lesser the energy consumption better the network lifetime. From Fig 6 and 8, it can be seen that the energy consumption of the proposed system is slight lesser than the exiting system. This is because of avoiding the looping due to path construction. Fig. 9 shows the remaining energy for various set of nodes in the network which shows better compared to the existing system. As a result, the overall network lifetime of the proposed system gets improved and shown in Fig. 7. NRO is Normalized Routing Overhead which is less for less number of packets and increases when the number of packet increase. Fig. 10 shows the NRO comparison, it increases with increase in number of nodes. Comparatively NRO is less in the proposed system then the existing system. The entire system performance is slightly improved by selecting the best shortest path for data transmission.

IV. Conclusion

The proposed system is a modified version of the existing algorithm. shortest path route construction is performed followed by node selection and cluster formation using GA. PSO is used for coverage model. Tracking is performed with the help of nodes position, velocity, acceleration and angle. The performance of the proposed system is compared with the existing system. It can be seen from the results the proposed system shows slight better results than the existing system. As the proposed system relay on best path selection results in better performance. The work can be further extended on tracking the target at various speed and different dimensions.

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