Performance Evaluation of Various Energy Efficient Routing Based on Localization using CMDS, NN & GA in Wireless Sensor Networks

Urvashi Singh, Manish Kumar Jha

Abstract— Localization and location aware energy efficient routing are two aspects of wireless sensor networks that have gained tremendous importance among researchers due to its wide application. Sensor nodes are deployed randomly and they self organize themselves to form a network to perform assigned duties. Most of the work treats localization as one aspect of WSN. Researchers working on location aware routing assume that the position of nodes is known by some algorithm. In this work the determination of position of nodes (Localization) and location aware energy efficient routing are done to understand the effect of good localization on energy efficient routing. The results of Compass Routing & Greedy Distance Algorithm based on localization using CMDS, NN & GA is compared for energy efficiency in the network.

Keywords— Localization, wireless sensor network, CMDS, neural network, GA, Greedy routing, Compass routing.

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1. INTRODUCTION

RECENT advances in MEMS fomented the growth of thousands of wirelessly distributed sensor nodes in the sensing field known as wireless sensor network (WSN). Sensor nodes are generally extremely small in size, low cost, less battery capacity with limited processing capability. WSNs find application in myriad applications such as wildlife monitoring, habitat monitoring, defence, etc. Many of these applications require localization of sensor nodes to determine the exact place of occurrence of event. This may be done on the basis of distance or angle measurement between sensor nodes. Localization is achieved by broadly two techniques [1-2] *(i) Range based technique (ii) Range free technique*. Former technique gives distance or angle information between sensor nodes including various methods such as Received Signal Strength (RSS), Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA). Later technique determines the information of localization using only the radio connectivity between sensor nodes by methods such as Multidimensional Scaling Technique (MDS), Centroid, Approximation Point In Triangle (APIT).

Range-based localization is of low location error, but it requires expensive hardware, and they consume more energy. Range-free localization requires low hardware cost with less energy requirement; but its localization error is much more than range-based techniques [3].

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Other than localization, other existing challenges for WSN are limited energy source, memory & computational capabilities. In this work localization is done by three technique: *CMDS*, *NN* & *GA*. Based on location awareness, energy efficient routing is applied using *Compass Routing* and *Greedy Distance Algorithm*. The results of Compass Routing & Greedy Distance Algorithm based on localization using CMDS, NN & GA is compared for energy efficiency in the network. Localization is performed in MATLAB & routing using QUALNET 6.1.
The rest of the paper follows with related work in section 2. Problem formulation is described in section 3 followed by simulation scenario & results in section 4. The paper ends with conclusion in section 5.

2. RELATED WORK

Georgious Latsoudas *et al.* in [2] proposed a two-stage MDS algorithm that utilizes an algebraic initialization procedure followed by gradient descent. The algebraic initialization step is based on the Fastmap algorithm. Fastmap [9] is a linear-complexity mapping tool which is sensitive to measurement errors. Stephan H. Chagas *et al.* in [4] proposed an artificial Neural Network (ANN) approach to localization in wireless sensor network through adjustment of ANN structure using GA. Result obtained after optimization had a root mean square error of 0.41meter, a maximum error of 1.07 meter & a minimum error of 0.041 meter. Mohammad Shaifur Rahman *et al.* in [5] propose a flexible model based on neural network and grid sensor training phase for accurate localization of sensors. Simulation results show that the location accuracy can be increased by increasing the grid sensor density and the number of access points. S. Rajaee *et al.* in [6] addresses localization techniques in ad-hoc wireless networks. They reviewed and proposed a localization method that by using probabilistic neural network (PNN) estimates the locations of unknown nodes. Then they reduce calculations and energy consumption with the help of Independent Component Analysis (ICA) by removing some unnecessary anchor nodes.

Several authors have dealt with the problem of localization and energy efficient routing separately. This work studies the effect of localization on effective routing to determine the energy efficient techniques.

3. PROBLEM FORMULATION

3.1 Generalized Localization

- Let Nw be the WSN and S_i the set of all sensor nodes for communication process in Nw.
- Consider all $S_i \in Nw$ where $i = 1,2,3,........n$.
  Set of all neighbour of S_i, in Nw is announced as $nbr(S_i)$.
- Geographical emplacement of each S_i is represent as $gep_i = (x_i, x_j)$. Assuming that using RSS technique to estimate distances D_{ij} between each sensor nodes S_i as $d_{ij} = \|x_i - x_j\|$ where $i, j = 1,2,3,....., N$.
- Ranging error occurs in the distance measurement due to some factors like multipath fading, path loss factors etc. resulting in an approximate geographic node emplacement as $gep_i' = (x_i', x_j')$.
- Thus location error for sensor nodes in network is $\partial_i = \|gep_i - gep_i'\|$.
- Figure of merit for location estimate is given by *STRESS* function.

$$Rawstress = \sum_{i,j} (d_{ij} - d_{ij}^{o})^2 \qquad (1)$$

Using Normalization Factor, NF (sum of squared deviation from mean), *Stress*:

$$Stress = \sqrt{\frac{rawstress}{NF}} \qquad (2)$$

3.2 Localization using Classical Multidimensional Scaling (CMDS)

For nodes $S_i = [s_1,........., s_n]$, CMDS gives relative node position $S_i' = [s_1',....., s_n']$ where $i = 1,2,3,........n$ is number of nodes. Distance matrix D_{ij} between all pair of nodes can be calculated as $d_{ij} = D_{ij} = \| x_i - x_j \|$ where $i, j = (0,1,2,.........., n)$. Compute square distance matrix D_2, as $[D_2]_{ij} = d_{ij}^2$. Obtained symmetric matrix *B* from D_2 as $B = -\frac{1}{2} J D_2 J$, where $J = I_{n+1} - \frac{1}{n+1} 1_{n+1} 1_{n+1}^T$ where I_{n+1} is an ($n+1 \times n+1$) identity matrix & $I_{n+1} = [1,1,1,...,1]^T$ is an $n+1 \times 1$ unit vector. Applying SVD as UVU^T where V is a diagonal containing corresponding eigen values, U is composed of eigen vector, thus relative points X' is obtained as $X' = B \wedge \frac{1}{2}$. As *n+1* nodes are placed in *m* dimensional space relative points X' are obtained by $X' = U_m V_m^{\frac{1}{2}}$ [7].

3.3 Localization using Neural Network (NN)

A circuit or network of biological neurons is referred as NN. In our work we opt for NEWCF neural network shown in figure 1 for estimating the node's position. Newcf network is a Cascaded - forward network consisting of N1 layers using DOTPROD weight function, NETSUM net input function, and the specified transfer function. The first layer has weight coming from the input. Each subsequent layer has weight coming from the input and all previous layers. All layers have biases.

Here, positioning of nodes obtained after CMDS is taken as input of NN. Nodes are treated as neurons S_i where $i = 1,2,3,........n$, are multiplied with weight function $w_1, w_2,......, w_n$ where $w_n \in W$ together with bias function, $bs_i \in B$ where $i = 1,2,3,........n$ and applied over transfer function that gives the position of the nodes as given in equation 3.

$$\sum_{i=1}^{n} w_n S_i + bs_i \qquad (3)$$

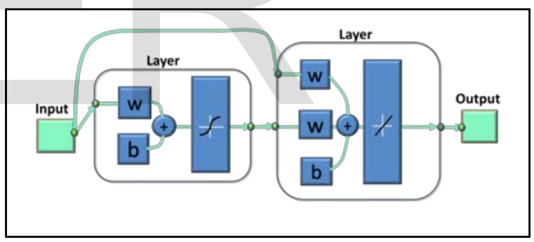

Figure 1 newcf neural network

3.4 Localization using Genetic Algorithm

Genetic Algorithm begins with a set of solutions (represented by chromosomes) called population. Solution from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one. Solutions which are selected to form new solution (offspring) are selected according to their fitness function.

Consider randomly deployed sensor nodes with known position. Distance matrix d_{ij}

$$d_{ij} = \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & d_{n3} & d_{nn} \end{bmatrix}_{n \times n} \qquad (4)$$

Between each sensor is assumed to be known from RSS, where *n* is number of sensor nodes. Distances in the matrix is converted to eight bit binary data equal to *C* which is considered as original population. Crossover and mutation is applied on

ISSN 2229-5518

selected rows of matrix C to obtain a new matrix $C^{'}$. Process of GA continues till stress obtained is less that obtained through CMDS.

$$C = \begin{bmatrix} e_8,......,e_2,e_1,e_0 & f_8,......,f_2,f_1,f_0 & g_8,......,g_2,g_1,g_0 & h_8,......,h_2,h_1,h_0 \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ o_8,......,o_2,o_1,o_0 & p_8,......,p_2,p_1,p_0 & q_8,......,q_2,q_1,q_0 & r_8,......,r_2,r_1,r_0 \end{bmatrix}_{n \times n} \quad (5)$$

$$C^{'} = \begin{bmatrix} e_8^{'},......e_2^{'},e_1^{'},e_0^{'} & f_8^{'},......f_2^{'},f_1^{'},f_0^{'} & g_8^{'},......g_2^{'},g_1^{'},g_0^{'} & h_8^{'},......h_2^{'},h_1^{'},h_0^{'} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ o_8^{'},......o_2^{'},o_1^{'},o_0^{'} & p_8^{'},......p_2^{'},p_1^{'},p_0^{'} & q_8^{'},......q_2^{'},q_1^{'},q_0^{'} & r_8^{'},......r_2^{'},r_1^{'},r_0^{'} \end{bmatrix}_{n \times n} \quad (6)$$

3.5 This research comprises of two energy efficient routing protocol *(i)* Compass routing protocol *(ii)* Greedy distance routing protocol. For energy efficient routing of localized network few assumption are considered [8]:

- All nodes know their geographic location.
- Each nodes are aware of their intermediate neighbour who is within the radio range of whom.
- Routing destination is specified as a node with a given location.

(i) Compass routing protocol

For delivering packets from source node to sink node, this protocol seeks the minimum angle formed by the node to its neighbouring nodes in one hop & among the nodes with angle less than 180^0. Coloured dotted circle as shown in figure 2 shows the boundary range of selected node. Node *A, B, C, M & N* comes under the range of source node from this source node, node B & A forms $\angle 1 \& \angle 2 \langle 180^0$. For further delivery of packets node B is selected as source node to sink node as it has less angle than A. Select the nodes which comes under the range of node B again selecting a neighbour formed angle less than 180^0 forward the packet to that node, likewise continue the process for the packets to reach to the sink node for delivery of packet.

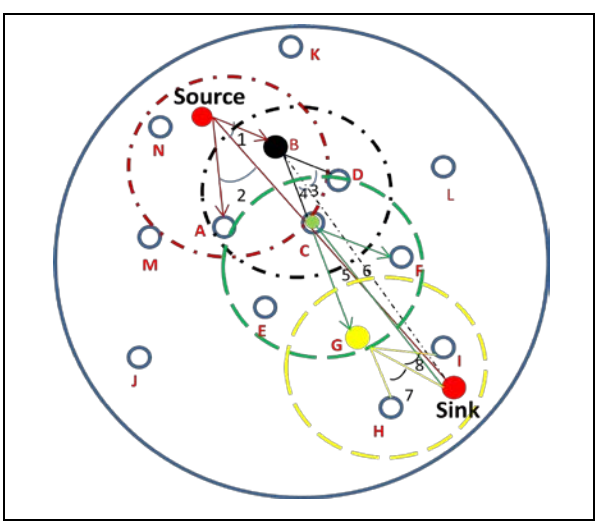

Figure 2. Compass routing algorithm

(ii) Greedy distance algorithm

A greedy routing algorithm is based on euclidean distance as shown in figure 3. This routing protocol states that among the neighbouring nodes, the one that is closest to sink is selected for packet forwarding.

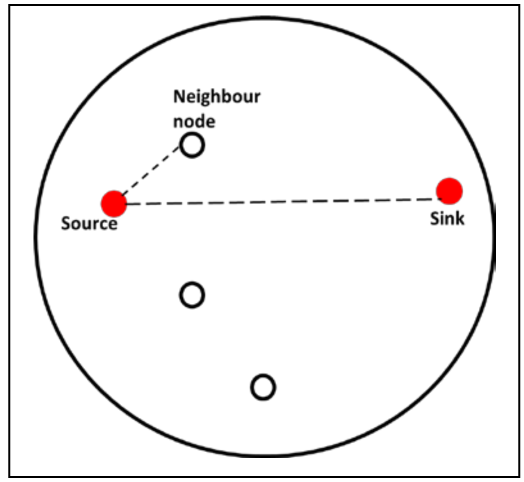

Figure 3. Greedy distance algorithm

4 SIMULATION SCENARIO & RESULTS

Routing in this research is carried out by using QUALNET 6.1. Terrain size is selected on the basis of localized 100 sensor nodes connected wirelessly along with traffic gen application. Simulation time for whole process is 200 seconds. Figure 4 & 5 shows scenario for CMDS compass routing & greedy distance routing, figure 6 & 7 shows scenario for genetic algorithm for compass routing & greedy distance routing protocol. Figure 8 & 9 are scenarios for NN compass routing & greedy distance routing protocol.

In this research initially 100 nodes are localized in MATLAB using CMDS technique. These localized nodes are used to deliver the packets from source (node id 74) to sink (node id 65) aiming less power consumption, which shall increase the lifetime of whole network. This works attempts to show energy efficiency of WSN on the basis of residual battery from source (node id 74) to sink (node id 65) using both routing protocols shown in figure 10 & 11.

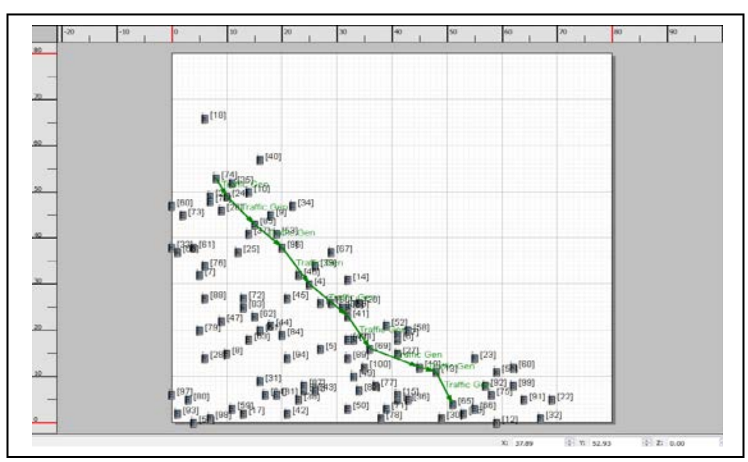

Figure 4 Simulation scenario for CMDS compass routing protocol

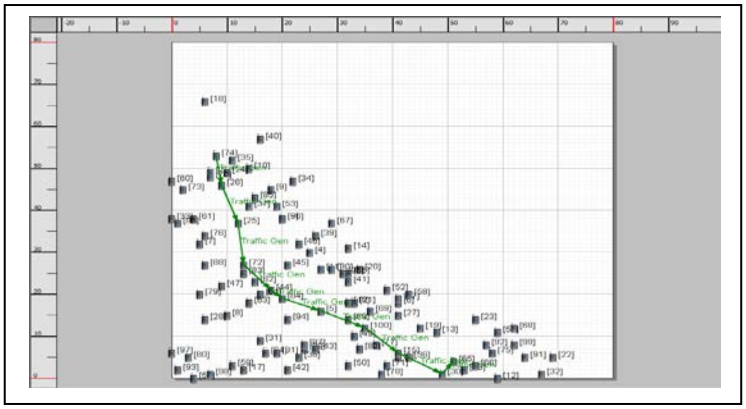

Figure. 5 simulation scenario for CMDS greedy distance routing protocol

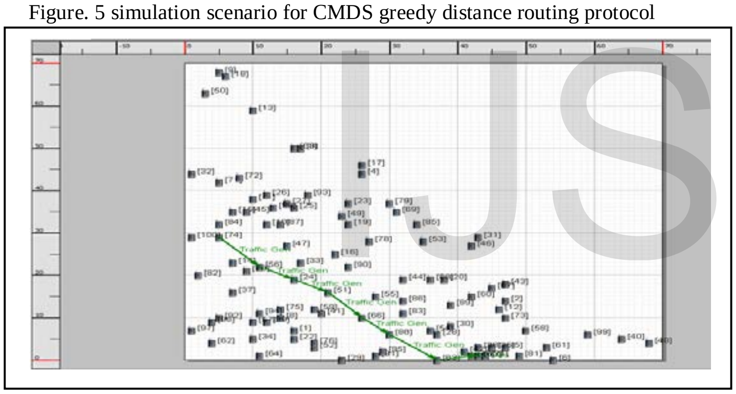

Figure 6 simulation scenario for GA compass routing protocol

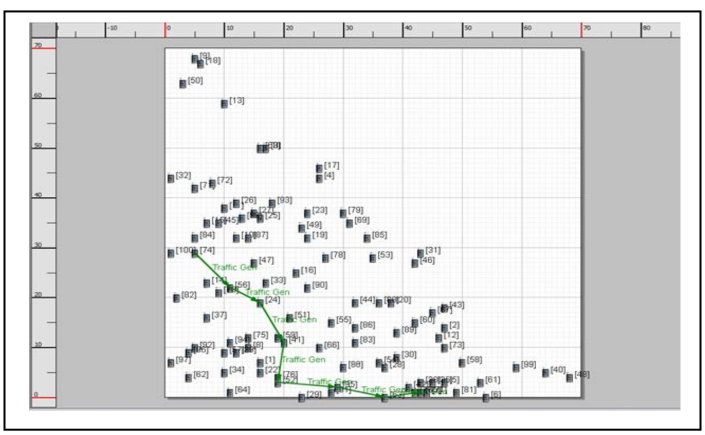

Figure. 7 Simulation scenario for GA greedy distance routing protocol

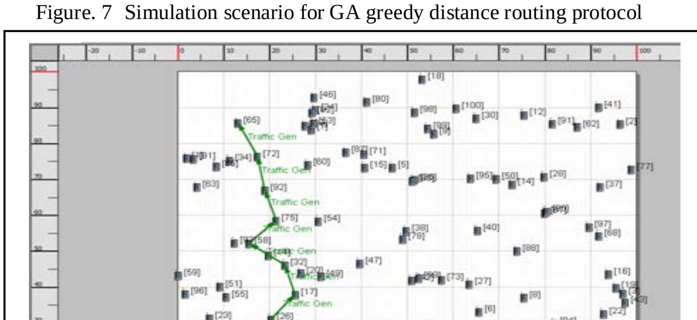

Figure 8. Simulation scenario for NN compass routing protocol

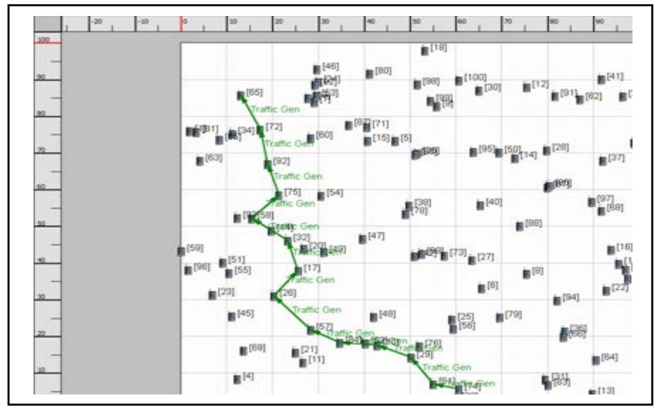

Figure 9. Simulation scenario for NN greedy distance routing protocol

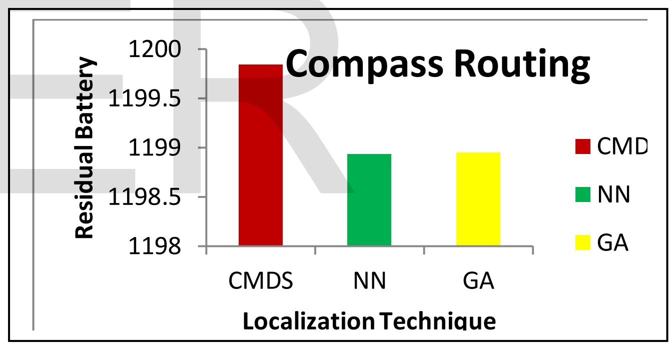

Figure. 10 Comparison for CMDS, NN & GA for compass routing on the basis of residual battery

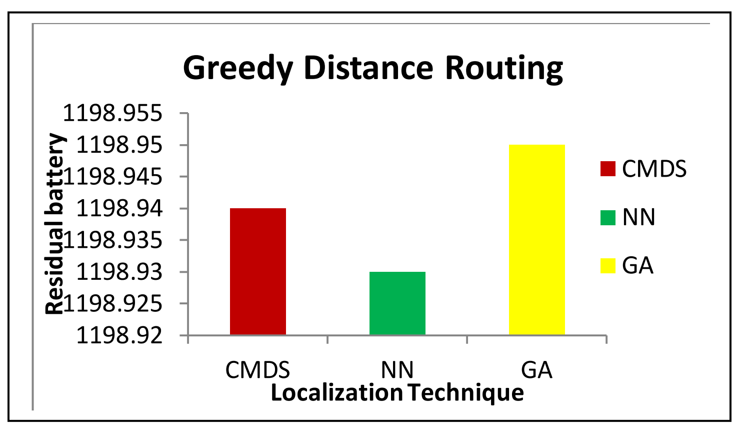

Figure.11 Comparison for CMDS, NN & GA for greedy distance routing on the basis of residual battery

5 CONCLUSION

It is observed from figure 10, residual battery is highest with CMDS localization when Compass routing is applied. Residual battery is more or less same in case with NN & GA based localization. NN & GA based localization gives better positioning of nodes and hence it is expected to consume more energy traversing actual path. Figure 11 shows that residual battery is more with GA based localization with greedy distance routing. This result is encouraging as the position accuracy is also high. This work attempts to combine the analysis of localization and energy efficient routing. Most of the work treats localization as one aspect of WSN. Researchers working on location aware routing assume that the position of nodes is known by some algorithm. For effective energy efficient routing it is desirable to consider localization as initial part of routing as has been done in this work.

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