

# Energy Efficient Routing in Wireless Sensor Networks Using Fruit Fly Optimization Algorithm

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**Abstract – A Novel Energy-Efficient Min-Max Optimization (NEMO) is proposed to improve the data delivery performance in WSN. The NEMO scheme is used in the virtual grid (after partitioning the sensor field into uniform sized cells based on the number of nodes present in the sensor field) environment to periodically collect the data from the mobile sink through the cell headers. Here the movement of sink is based on controlled fashion (sink moves around the boundary of the sensor field environment) and collects the data from the border line cell headers. For efficient data delivery Fruit Fly Optimization (FFO) algorithm is applied here to find the best path by using the fitness value (smell concentration) calculated between the nodes based on the distance. Optimal path is chosen by first calculating the minimum hop count paths and then find the maximum of total fitness value along those paths. In that way best path is selected by considering the shortest path (since the fitness value is based on the distance) which improves the data delivery performance and also it minimizes the energy consumption. The proposed scheme enables the sensor nodes to maintain the optimal path towards the latest location of mobile sink by using the FFO algorithm which leads to maximize the network lifetime in wireless sensor networks.**

**Index Terms – Energy, optimization, data delivery, FFO, fitness value, network lifetime.**

## 1. INTRODUCTION

This The rapid advancement in the technology is based on the needs of fast, time efficient and self configurable mechanisms to monitor the physical conditions of the surrounding areas. Sensors became a technology that is more suitable for collecting the context from the real world. Wireless sensor networks consist of numerous sensor nodes (static or mobile) with sensing, computing and communicating capabilities to monitor and report the sensed data (temperature, pressure, humidity, speed, intensity) via wireless transceiver to the base station which act as a gateway between the WSN and other networks for further processing. Since sensor nodes are spread out into regions where sensor network is hard to monitor by itself. Hence to hold back the energy of these sensor nodes, utilizing the sink (static) plays an important role to minimize their effort for sending data. However, the nodes which are closer to sink are only responsible for forwarding

the data from the far away source nodes which give rise to energy-hole problem.

Sink's mobility [12] gained popularity to solve the above problem with two challenge tasks such as packet loss while collecting data from all sensor nodes separately and dynamic network topology caused by mobile sink. Since mobile sinks survey and collect the sensed data from the entire sensor field. However collecting the sensed data from all the sensor nodes is difficult when the number of sensor node gets increased. It takes a long time to collect all the sensed data from all sensor nodes separately. It will increase the packet loss ratio and also the battery of mobile sink runs over faster. So the CH (Cluster Head) is introduced to achieve the less packet loss. The nodes which are not CH's will forward their sensed data to its nearest CH and therefore mobile sink will visit only the CH's to collect the sensed data. To cope with dynamic network topology, nodes need to be aware of the updated latest location of the mobile sink for efficient data delivery. In order to gain the location of sink some data dissemination protocols like Directed Diffusion will periodically flood the sink's topological updates to the entire sensor field. Where flooding the sink's location to entire sensor field, leads to more energy consumption. Since here we are using the concept of CH so only a set of CH scattered in the sensor field are only responsible to keep track of sink's location. Network-wide dissemination of sink's location updates helps to improve the data delivery performance to the mobile sink thereby facilitating dynamic routes adjustments.

The application of wireless sensor networks to reduce the effort of human in various environments such as disaster management, intelligent transport system, battle field, healthcare environment and so on. Especially for sink mobility sensor nodes deployed at various points on interest (junctions, car parks, area susceptible to falling rocks) can provide early warning to drivers (mobile sink) in intelligent transport system.

Fruit Fly Optimization is an emerging method for understanding universal optimization predicated on the foraging comportment of the fruit fly. The sensory perception

of the fruit fly is better than that of other species, especially the sense of smell and vision. The olfactory organ of a fruit fly can collect sundry smells from the air, and even a virtual source 40 km away [7]. Afterwards, the fruit fly flies to the food, uses its acute vision to find the virtuals and where its fellows accumulate, and then it flies in that direction, as shown in Figure 1.

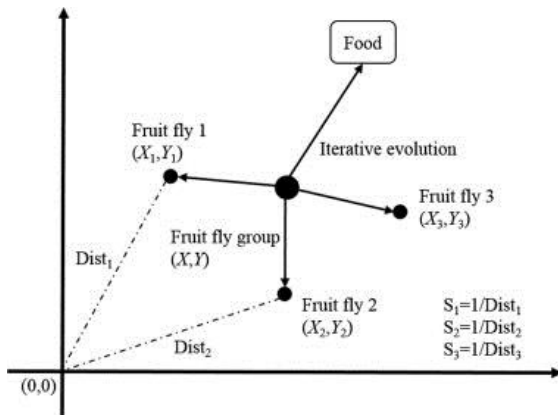


Figure 1 Iterative search for food of fruit fly swarm

The Fruit fly characteristics of searching for food are reduced to several necessary steps and procedure examples, as reference for readers [9]. The steps are described, as below:

**Step 1** The random initial position of a fruit fly swarm is as shown in the above Figure 1.

Init X\_axis; Init Y\_axis

**Step 2** Random direction and distance of searching for food using the sense of smell of a fruit fly individual.

$X_i = X\_axis + \text{Random Value}$

$Y_i = Y\_axis + \text{Random Value}$

**Step 3** As the location of food cannot be known, the distance (Dist) to the origin is estimated before the decision value of smell concentration (S) is calculated; this value is the reciprocal of distance.

$$Dist_i = \sqrt{X_i^2 + Y_i^2}$$

$$S_i = \frac{1}{Dist_i}$$

**Step 4** The smell concentration decision value (S) is substituted in the smell concentration decision function (also known as the Fitness function) to work out the smell concentration (Smelli) in the position of the fruit fly individual.

$Smell_i = \text{Function}(S_i)$

**Step 5** Determine the fruit fly with the maximum smell concentration among the fruit fly swarm (seek for the maximum value)

$[\text{bestSmell bestIndex}] = \max(\text{Smell})$

**Step 6** Retain the best smell concentration value and x, y coordinates, here the fruit fly swarm flies toward the position by vision.

$\text{Smellbest} = \text{bestSmell}$

$X\_axis = X(\text{bestIndex})$

$Y\_axis = Y(\text{bestIndex})$

**Step 7** Enter into iterative optimization, repeat execution steps 2-5, and judge whether the smell concentration is better than the previous iterative smell concentration, if yes, execute Step 6.

In the proposed approach fruit fly optimization algorithm is applied in the wireless sensor networks for selecting the best cluster head and best path selection (shortest path) based on the fitness value and hop count which minimizes the delay and improves the data delivery performance compared to the previous algorithms. The cluster head utilizes the energy efficiently for data transmission in wireless sensor networks.

## 2. RELATED WORK

All the related works related to the energy efficient routings are summarized below:

- Predictive Energy Consumption Efficiency
- Linear/Nonlinear Programming (LP/NLP) based on PSO
- Low Energy Adaptive Clustering Hierarchy (LEACH) offsets this by probabilistically rotating cluster heads role
- Hybrid ABCACO algorithm to solve a Nondeterministic Polynomial (NP) hard and finite problem
- LEACH protocol in cluster-head selection
- Inter- and Intra-cluster routing

### 2.1. Predictive Energy Consumption Efficiency

Zhang et al [1] proposed a new clustering routing method based on predictive energy consumption efficiency (PECE) for a wireless sensor network (WSN). Cluster formation and stable data transfer. When this algorithm selects the cluster head, the degree of the nodes and the relative distance are used, to have the better coverage performance but also short average distance from other member nodes in the formative cluster and the cost of communications within the clusters is

small. While considering the value of energy consumption, hop count and propagation delay on this route. To predict the route yield of each routing path from the source node to the sink node by using this strategy gives a precise definition of the route using two types of bee agent. Hence the optimization design of the algorithm can improve the quality of clusters, increasing the overall network performance and it balances the energy consumption of whole network and prolongs the survival time of the network.

## 2.2. Linear/Nonlinear Programming (LP/NLP) based on PSO

Pratyay Kuila and Prasanta Jana [2] studied an energy efficient clustering and routing are two well known optimization problems to extend lifetime of wireless sensor networks (WSNs). This paper presents Linear/Nonlinear Programming (LP/NLP) formulations of these problems followed by two proposed algorithms for the same based on particle swarm optimization (PSO). The routing algorithm is developed with an efficient particle encoding scheme and multi-objective fitness function. The clustering algorithm is presented by considering energy conservation of the nodes through load balancing. The proposed algorithms are experimented extensively and the results are compared with the existing algorithms to demonstrate their superiority in terms of network life, energy consumption, dead sensor nodes and delivery of total data packets to the base station.

## 2.3. Low Energy Adaptive Clustering Hierarchy (LEACH) offsets this by probabilistically rotating cluster heads role

Baskaran M and Sadagopan C [3] introduced a CH conveys information gathered by cluster nodes and aggregates/compresses data before transmitting it to a sink. However, this additional responsibility of the node results in a higher energy drain leading to uneven network degradation. Low Energy Adaptive Clustering Hierarchy (LEACH) offsets this by probabilistically rotating cluster heads role among nodes with energy above a set threshold. CH selection in WSN is NP-Hard as optimal data aggregation with efficient energy savings cannot be solved in polynomial time. In this work, a modified firefly heuristic, synchronous firefly algorithm, is proposed to improve the network performance.

## 2.4. Hybrid ABCACO algorithm to solve a Nondeterministic Polynomial (NP) hard and finite problem

Rajeev Kumar and Dilip Kumar [4] created a wireless sensor network more energy efficient, swarm intelligence technique has been applied to resolve many optimization issues in WSNs. This paper proposed a new hybrid ABCACO algorithm to solve a Nondeterministic Polynomial (NP) hard and finite problem of WSNs by combining the both algorithms ABC (to collect information from the field periodically) and ACO (to enhance the network lifespan). ABCACO algorithm is divided into three main parts:

Selection of optimal number of sub regions and further sub region parts, cluster head selection using ABC algorithm, and efficient data transmission using ACO algorithm. Hierarchical clustering technique is used for data transmission; the data is transmitted from member nodes to the sub cluster heads and then from sub cluster heads to the elected cluster heads based on some threshold value. Cluster heads use an ACO algorithm to discover the best route for data transmission to the base station (BS).

## 2.5. LEACH protocol in cluster-head selection

Qian Liao and Hao Zhu [5] presented the primary objectives of the wireless sensor network routing protocol design are balancing network energy consumption, improving the efficiency of data transmission and extending the entire network lifetime. This paper analyses the effectiveness of LEACH protocol in cluster-head selection, and proposes an improved clustering algorithm. This new algorithm takes node's residual energy and location information into account, optimizes the selection method of the threshold for electing cluster-head, improves optimal cluster-head selection strategy that is normal nodes select the optimal cluster-head based on the cost function.

## 2.6. Inter- and Intra-cluster routing

Sohail Jabbar and Abid Ali Minhas [6] presented an energy efficient routing scheme for throughput improvement in WSN. The proposed scheme exploits multilayer cluster design for energy efficient forwarding node selection, cluster heads rotation and both inter- and intra-cluster routing. To improve throughput, rotate the role of cluster head among various nodes based on two threshold levels which reduces the number of dropped packets.

# 3. PORPOSED MODELLING

## 3.1 Proposed System Architecture

NEMO enables sensor nodes to maintain nearly optimal routes to the latest location of a MS with minimal network overhead. It partitions the sensor field in a virtual grid of equal sized cells and constructs a virtual backbone network comprised of all the CH. Nodes close to the center of the cells are appointed as CHs, which are responsible for data collection from member nodes within the cell and delivering the data to the MS using the virtual backbone network.

The goal behind such virtual structure construction is to minimize the routes re-adjustment cost due to sink mobility so that the observed data is delivered to the MS in an energy efficient way. In addition, NEMO also sets up communication routes such that the end-to-end delay and energy cost is minimized in the data delivery phase to the MS. The MS moves along the periphery of the sensor field and communicates with the CHs for data collection.

Using NEMO, each and every CH calculates the fitness value among the neighbour nodes. In order to deliver data to the mobile sink it calculates the best optimal path based on the path having maximum fitness value for minimum hop count is chosen. Since the paths are selected based on the distance priority, shortest path is selected between the source and the sink nodes.

### 3.2 Module Description

The virtual grid structure is formed by partitioning the sensor field into uniform sized cells based on the number of nodes. The partitioning of sensor field is taken because of uniform workload on the part of CH nodes which expand the network lifetime. Cell size is partitioned from sensor network such that it should satisfy the range in between sensor node minimum range and sensor node maximum range as mentioned in the Table 1.

No. nodes (N)	Minimum and Maximum Range for CH Selection	No. CHs (K)
100	$1 < N \times 0.05 \leq 6$	4
200	$6 < N \times 0.05 \leq 12$	9
300	$12 < N \times 0.05 \leq 20$	16

Table 1 Network partition

NEMO elects CH in every cell, i.e. the node which is closest to the midpoint of the cell. The total number of nodes computes the midpoints of all the cells by the sensor field's dimension knowledge. In election process to reduce communication cost, the nodes whose distance to the midpoint of the cell having less threshold will only take part in the election. The threshold distance may increase during the election process if no node is found within the threshold distance. This election strategy helps in energy conservation and also elects CH at the appropriate position within the cell.

CH shares its status within the cell and slightly outside the cell boundary. Nodes associate themselves to the closest one when it receives notification from more than one CH. Nodes when receive multiple notifications it shares information to primary CH about the secondary CH. In this way, neighboring CHs form adjacencies using gateway nodes. The maximum CHs adjacent for the border line CH are 2, 3 whereas for an inside CH is 4. The virtual backbone structure type was

formed by the set of CH nodes together with the gateway nodes as shown in Figure 2.

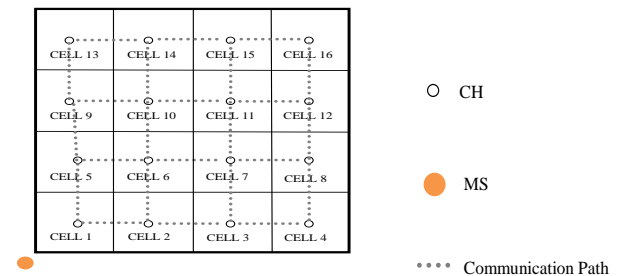


Figure 2 Virtual structure after establishing adjacencies

Now consider the sink is at coordinates (0, 0) communication routes are set up. The CHs adjust their routes to the MS initial position based on the communication routes set up.

#### 3.2.2 Shortest path routing using Fruit Fly Optimization Algorithm

The Fruit fly characteristics of searching for source node is based on the following necessary steps are described, as below:

**Step 1** The random initial position of a mobile sink is in (0, 0) coordinates such that,

$$\text{Init } X_{\text{axis}} = 0; \text{ Init } Y_{\text{axis}} = 0$$

**Step 2** Controlled direction of mobile sink and distance of searching for source using the fitness value of each CH individuals. The direction of the mobile sink is based on the boundary of the sensor field.

(a) For all bottom movement:

$$X_i = X_{\text{axis}} + 20$$

$$Y_i = Y_{\text{axis}} + 0$$

(b) For all right movement:

$$X_i = X_{\text{axis}} + 0$$

$$Y_i = Y_{\text{axis}} + 20$$

(c) For all top movement:

$$X_i = X_{\text{axis}} + 20$$

$$Y_i = Y_{\text{axis}} + 0$$

(d) For all left movement:

$$X_i = X_{\text{axis}} + 0$$

$$Y_i = Y_{\text{axis}} + 20$$

**Step 3** As the location of the neighbor CHs can be known, hence the distance (Dist) to the neighbor CH nodes are estimated before the decision value of smell concentration (S) is calculated; this value is the reciprocal of distance.

$$Dist_i = \sqrt{X_i^2 + Y_i^2}$$

$$S_i = \frac{1}{Dist_i}$$

**Step 4** The smell concentration decision value (S) is substituted in the smell concentration decision function (also known as the Fitness function) which is the sum of the total fitness value of the path to work out the smell concentration (Smelli) in the position of the mobile sink.

$$Smell_i = \text{Function}(S_i)$$

**Step 5** Determine the path having minimum hop count and maximum smell concentration among the paths.

$$[\text{bestSmell possiblePath}] = \min(\text{hop count})$$

$$[\text{bestSmell bestPath}] = \max(\text{Smell})$$

**Step 6** Retain the best smell concentration value and the path here the mobile sink collects data toward the position by using fitness value.

$$Smell_{\text{best}} = \text{bestPath}$$

**Step 7** Enter into iterative optimization, for each and every position of mobile sink which moves along the sensor field in a controlled manner.

Figure 3 shows the data delivery path using Fruit Fly Optimization algorithm.

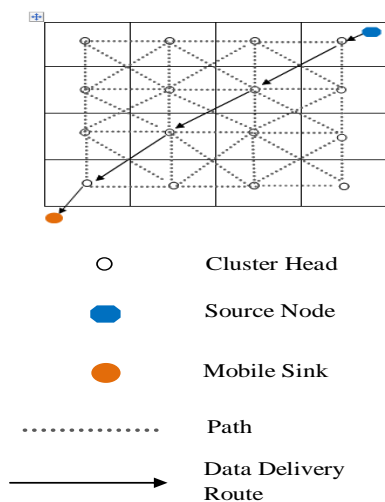


Figure 3 Data delivery path using Fruit Fly Optimization algorithm

### 3.2.3 CH rotation

The CH being the local data collector is vulnerable to high energy dissipation and therefore to prolong the network lifetime, the CH role needs to be distributed among the nodes within the cell. In order to achieve uniform energy dissipation, the NEMO scheme keeps track of the residual energy level of the current CH, where if it gets below a certain threshold, the new CH election is initiated by the current CH. In the re-election process, the node that is relatively closer to the midpoint of the cell and has a higher energy level compared to other candidates is elected as the new CH. In order to preserve the virtual backbone structure, the current CH before stepping down, shares the information of the new CH not only with all its member nodes but also with the adjacent CHs in its neighborhood. The data flow diagram for CH rotation is mentioned in the Figure 4

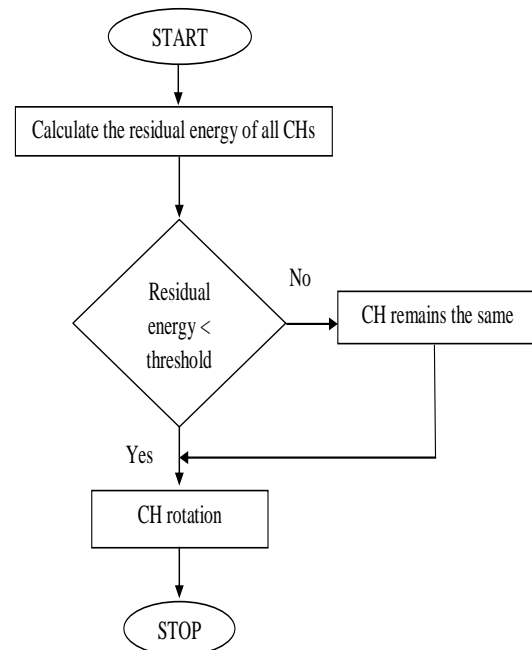


Figure 4 Data flow diagram for CH rotation

## 4. RESULTS AND DISCUSSIONS

Figure 5 represents the comparison between Nodes and Energy. Nodes using NEMO scheme incur less energy compared to the VGDRA scheme because of taking the path within the shortest distance to the mobile sink involves minimum energy. The NEMO scheme, using the average node energy consumption in reconstructing the data delivery routes to the latest location of mobile sink.



Figure 5 Energy efficiency for different network sizes

#### Packet delivery ratio

Figure 6 indicates the packet delivery performance. The packet delivery ratio can be calculated as the ratio between transmitted and received for overall packets. NEMO algorithm and VGDRA are compared with node variation. When sensor nodes increased from 100 to 300 nodes in the environment, the packet delivery ratio is decreased in both the algorithms but NEMO achieves more packet delivery ratio compared to VGDRA.

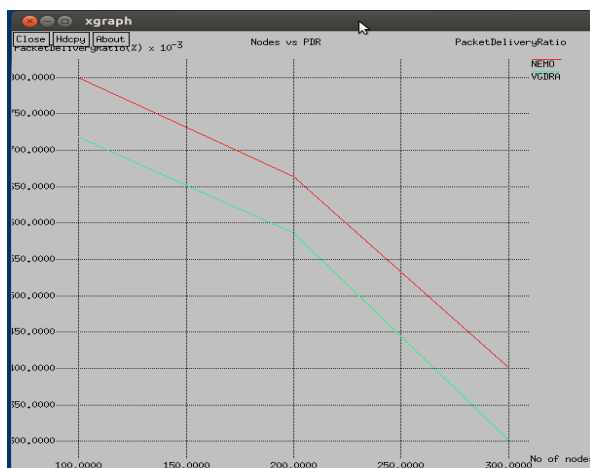


Figure 6 Packet delivery for different network sizes

#### Delay

The delay time is an indirect reflection of the data delivery efficiency as the more promptly the nodes come to know about the latest location of a mobile sink, the most efficient routes they can select in disseminating the sensed data. Figure 7 represents the delay time of the NEMO is minimum

compared to VGDRA when the sink is moving at a speed of 10 m/s.

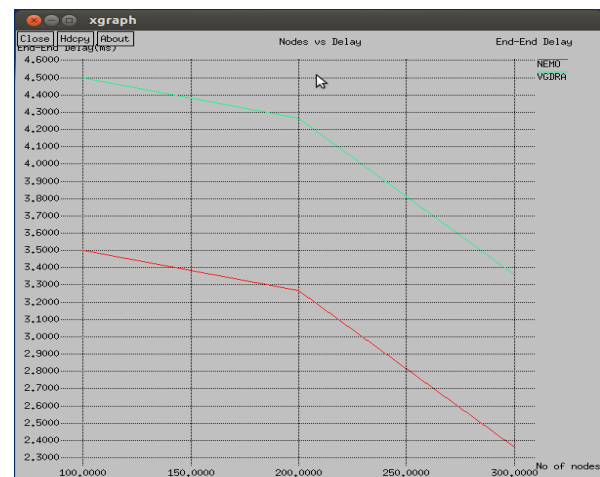


Figure 7 Delay time for different network sizes

## 5. CONCLUSION

A Novel Energy-Efficient Min-Max Optimization (NEMO) is proposed to improve the data delivery performance in WSN scheme that incurs least communication cost while maintaining nearly optimal routes to the latest location of the mobile sink. In NEMO scheme partitions the sensor field in a virtual grid and constructs a virtual backbone structure comprised of the CH nodes. A mobile sink while moving around the sensor field keeps on changing its location and interacts with the CHs for data collection. Using a set rules based on fruit fly optimization such as min-max optimization best optimal path is chosen between the source and sink node. In terms of nodes energy consumption and packet delivery ratio, the simulation results reveal improved performance of our NEMO scheme for different network sizes. Considering the scope of this project, security is not included. In future work, security will be implemented between the intermediate nodes, In order to achieve secure data transmission.

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