# Uneven Clustering Routing Protocol for Wireless Sensor Networks based on Fruit Fly Optimization Algorithm

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## Abstract

**For the energy and computing capability of nodes are limited in Wireless sensor networks (WSNs). In order to decrease the dead speed of the nodes, proposes an uneven clustering routing protocol for wireless sensor networks based on Fruit Fly Optimization Algorithm (FOA-UCR). By using Fruit Fly Optimization Algorithm to select a set of optimal nodes as cluster heads and selects secondary nodes from member nodes to cooperate with cluster heads to transmit data to base station. FOA-UCR uses greedy algorithm to find optimal path to communicate with base station. Simulation results demonstrate that this protocol can efficiently balance the energy consumption of network, and prolong the network lifetime.**

## Keywords

**Wireless Sensor Networks, Uneven Clustering, Fruit Fly Optimization Algorithm, Routing Protocol.**

## 1. Introduction

Wireless sensor has the characteristics of small size and low cost. At present, wireless sensor network has been widely studied and applied.It is widely used in target tracking, intrusion detection, environmental monitoring and traffic control. It has broad application foreground and commercial value. However, wireless sensor networks are usually deployed in harsh environments or unattended areas, and the sensor nodes are energy limited, it is difficult to replace the battery, so how to use the energy of wireless sensor node efficiently and make the entire network has a long stable working time is one of the most important research in wireless sensor network. At present, the domestic and foreign scholars have made a lot of research on the energy balance of wireless sensor networks. LEACH[1] is a typical clustering routing protocol. The cluster head nodes are randomly selected in a circular way, and the energy load of the whole network is evenly distributed to each node. LEACH can reduce the energy consumption of the network and prolong the entire network lifetime. However, there are some shortcomings in the LEACH protocol, such as cluster head distribution and single-hop communication between cluster head and base station, which can lead to premature death of cluster head nodes. EEUC [2] adopts unequal clustering method and inter-cluster multi-hop routing protocol, which uses distance between node and base station to set different cluster head competition radius, so ,the network can be divided into different sizes of clusters.Cluster heads using multi-hop routing protocol to communicate with base station. EEUC achieves the purpose of balanced the energy consumption of cluster heads. DEBUC[3] is proposed based on EEUC. It also uses nonuniform clustering and inter-cluster multi-hop routing. It adopts time-based cluster head competition algorithm according controlling the competition algorithm of candidate cluster head of different location. The geometric size of the nearest cluster is small, Cluster heads which are closer to base station consumption less energy in intra-cluster communication, the saving energy can be used to transfer data from other cluster heads. DEBUC can effectively save the energy of the single node, balance the energy consumption of the network and prolong the network lifetime. DSBCA[4] uses the same nonuniform clustering method as in reference[2][3], Taking full account of the residual energy of the node, the number of cluster heads, the density of the nodes in the cluster when select cluster heads. Simulation result demonstrate that DSBCA can prolong the lifetime of network. LEACH-PSOC[5] uses the particle swarm algorithm which has the character of converge quickly and strong global optimization capability to divide the entire network monitoring area into sub-areas of different sizes. Then electing cluster head node in every cluster according residual energy of cluster heads and the position of node. CMRAOL [6] improved the cluster head election algorithm in LEACH to avoid cluster head communicate with base station directly. Member nodes communicate with cluster head by single hop but cluster heads communicate with base station though multi-hop. LEACH-PSOC reduce the energy consumption of cluster heads which are far from base station, save and balance energy consumption and prolong network lifetime. UCDP [7] uses a reasonable dynamic partition strategy, in order to balance the energy consumption between regions, UCDP adopts unequal clustering method based on energy and the distance between nodes and base station to balance the energy consumption. Firstly, UCDP divides network into several regions, then, every region are divided into clusters according competition radius. Region heads to cooperate with cluster heads to transfer data to base station. UCDP has good stability and prolong the network life.

I-PSOC [8] uses the improved particle swarm algorithm to improved fitness function, making the cluster more reasonable, and adopts multi-hop method to balance the entire network energy consumption. Reference [9] to [11] use ant colony algorithm, fish swarm algorithm and artificial bee colony algorithm to improve the clustering process or the optimal multi-hop path, which can reduce the energy consumption of the whole network, avoid hot areas, and prolong the network lifetime.

This paper presents a load-balanced non-uniform clustering routing protocol (FOA-UCR). FOA-UCR uses fruit fly optimization algorithm to select a group of best nodes as cluster heads, and divide the monitoring area into clusters of different sizes. Every cluster selecting a secondary node to transfer data to base station, it can efficiently reduce the energy consumption of cluster heads and achieve an obvious improvement on the network lifetime.

## 2. Fruit Fly Optimization Algorithm

Fruit fly optimization algorithm [12] (FOA) was proposed by Pan Wencao in 2011.It is a new global optimization algorithm according to observe fruit flies hunt for food. Fruit flier use visual superiority to find food when the fruit flies id is far from food, otherwise use smell superiority to find food.So, fruit flies can find food quickly. Compared with particle swarm algorithm, FOA has the advantages of simple, less parameters, easy to adjust, small computation, strong global search ability and high precision [13].

## 3. System Model

### 3.1 Network Model

Assuming that there are N sensor nodes are randomly distributed in the M*M region, the position of node is fixed and every node equip location device. Other assumptions are as follows:

The position of the base station is fixed ,the energy of base station is not restricted but all nodes' energy is limited.

All nodes have equal status and similar processing and communication capabilities.

The nodes can judge the distance from the signal source through the strength of the signal, and adjust the transmission power.

Nodes use data fusion technology to reduce the amount of data transmission.

Every node has the same probability of being elected cluster head and secondary node.

Each node can communicate with base station directly.

### 3.2 Energy Consumption Model

FOA-UCR uses first order radio model, the energy consumption of transmitting data:

$$E_t\left(l,d\right)=\begin{cases} l\times E_{elec}+l\times E_{fs}\times d^2, d\le d_0 \\ l\times E_{elec}+l\times E_{mp}\times d^4, d>d_0 \end{cases} \quad (1)$$

$l$ is packet size, $d$ is transmission distance, $E_{elec}$ is radio frequency energy consumption coefficient, $E_{fs}$ and $E_{mp}$ are power amplifier circuit energy consumption coefficient in two kinds of channel propagation model.

The energy consumption of receiving data:

$$E_r\left(l\right)=l\times E_{elec} \quad (2)$$

In this paper, $E_{elec}$ =50nJ/bit, $E_{fs}$ =10nJ / bit/ m$^2$, $E_{mp}$ = 10nJ/bit/m$^4$.Cluster head takes data integration, reduce redundant data transmission. Assumption that no matter how much data is received, cluster head fuse data to $l$ bit. The energy consumption of fusing data:

$$E_k=l\times E_d \quad (3)$$

$E_d$ =5nJ/bit.

## 4. FOA-UCR Protocol.

FOA-UCR use centralized control strategy and looping mechanism base on rounds, firstly, all nodes send their own location, residual energy and other information to the base station. Then, selecting cluster heads and secondary nodes and base station broadcast the information of cluster heads and secondary nodes, other nodes join cluster according minimum communication cost principle.Fig. 1 shows the basic principle of FOA-UCR, the black circle represents cluster, The arrow indicates the direction of transfer data.

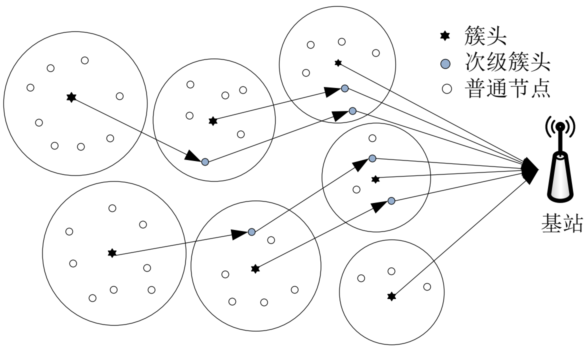


Fig. 1 The basic principle of FOA-UCR

### 4.1 Temporary Clustering

FOA-UCR selects candidate cluster heads by (4).

$$T=\begin{cases} \dfrac{p}{1-p\left(r\cdot \mathrm{mod}\dfrac{1}{p}\right)} & n\in G \\ 0 & n\notin G \end{cases} \quad (4)$$

$T$ is threshold, $p$ is the probabilities of nodes to be cluster heads, $r$ is the number of cycles, $G$ is a collection of nodes which have not been selected as cluster head in recent $\frac{1}{P}$ rounds. Every node generated a random number $\tau\left(\tau \in (0,1)\right)$,if $T < \tau$ ,The node becomes the candidate cluster head node and other nodes go dormant which are within candidate cluster head radius.

$R_{comp}^{o}$ is maximum competitive radius, maximum distance to base station, $d_{max}$ is the maximum distance between nodes and base station, $d_{min}$ is the minimum distance between nodes and base station. $d\left(n_i, bs\right)$ is the distance between candidate node and base station. $\beta \in (0,1)$. It is easy to know that competition radius of candidate cluster heads between $(1-\beta)R_{comp}^{o}$ and $R_{comp}^{o}$ . Then nodes send message to join cluster with minimal communication cost.

## 5. Cluster Head Selection

Cluster head is mainly responsible for the collection of data within the cluster, and fuse the data. In order to balance the energy consumption of each node in the network, define the fitness function as

$$Fitness(s) = \frac{\max\left(d_k\left(TenCH_i, BS\right)\right)}{\sum_{k}^{C_{k.NN}} d\left(Node_j, TenCH_i\right) \Big/ C_{k.NN}} E_{C_k.TenCH_i} \tag{5}$$

$$1 \le i \le C_{k.NT}, 1 \le k \le K$$

$K$ is the number of clusters in network, $d_k\left(TenCH_i, BS\right)$ is the distance between tentative heads and base station, $d\left(Node_j, TenCH_i\right)$ is the distance between node and tentative cluster head, $C_{k.NN}$ is the number of nodes in cluster k, $E_{C_k.TenCH_i}$ is the residual energy in of tentative k.

Step 1: Assuming that the tentative cluster head is the fruit flies which has the highest smell concentration, and store the best smell concentration and coordinates.

$$NodeX_{axis} = NodeX\left(TempCH_i\right) \tag{6}$$

$$NodeY_{axis} = NodeY\left(TempCH_i\right) \tag{7}$$

$$[bestSmell\ bestIndex] = Fitness\left(TempCH_i\right) \tag{8}$$

$$Smellbest = bestSmell \tag{9}$$

$$NodeX_{best} = NodeX\left(bestIndex\right) \tag{10}$$

$$NodeY_{best} = NodeY\left(bestIndex\right) \tag{11}$$

Step 2: Initial M fruit flies in every cluster.

$$InitX(m) = h * rand() \tag{12}$$

$$InitY(m) = h * rand() \tag{13}$$

$h$ is step length. Computing the fitness value of fruit fly according

Step 3: Define the random direction and distance for fruit flies to search food according to the sense of smell.

$$NodeX_i = InitX(m) + t * rand() - t \tag{14}$$

$$NodeY_i = InitY(m) + t * rand() - t \tag{15}$$

Nodes are distributed randomly, it is difficult for fruit flies to find nodes according (14) and (15).Assumption $\triangle p_x$ is the distance between fruit fly and node j in x-axis, $\triangle p_y$ is the distance between fruit fly and node j in y-axis,

$$\triangle p_x = \left| NodeX_i - NodeX\left(Node_j\right)\right| \tag{16}$$

$$\triangle p_y = \left| NodeY_i - NodeY\left(Node_j\right)\right| \tag{17}$$

So

$$\triangle p_i = \sqrt{\triangle p_x{}^2 - \triangle p_y{}^2} \tag{18}$$

$$\triangle p_m = \min\left(\triangle p_1, \triangle p_2, \cdots, \triangle p_n\right) \tag{19}$$

Finding the node which is the nearest node to fruit fly, then, adjust the random flight direction and distance of fruit fly.

$$NodeX_i \approx NodeX\left(Node_m\right) \tag{20}$$

$$NodeY_i \approx NodeY\left(Node_m\right) \tag{21}$$

Step 4: Computing the distance between fruit fly and tentative head, because the position of food is unknown .The smell concentration value can be defined by distance.

$$Disti = \sum_{k}^{C_{k,NN}} d\left(Node_j, TenCH_i\right) \tag{22}$$

$$Si = \frac{1}{Disti} \tag{23}$$

Step 5: Taking smell concentration value into fitness function and computing the largest value.

$$Smelli = Fitness\left(S_i\right) \tag{24}$$

$$[bestSmell\ bestIndex] = \max\left(Smelli\right) \tag{25}$$

If

$$Smellbest < bestSmell \tag{26}$$

So

$$Smellbest = bestSmell \tag{27}$$

Determine the cluster head position:

$$NodeX_{best} = NodeX\left(bestIndex\right) \tag{28}$$

$$NodeY_{best} = NodeY\left(bestIndex\right) \tag{29}$$

Step 6：Iterative optimization, repeat steps 2 to 5until the times of repeat is greater than Maxgen to get the optimal solution , then the cluster head selection is finished. All tentative heads and temp cluster heads become normal node.

After every node join the cluster, cluster head select secondary node according (30).

$$W\left(h\right) = a\frac{\overline{E}}{E_r} + b\frac{\overline{d}}{d\left(h, BS\right)} \tag{30}$$

$\overline{E}$ is average residual energy of member nodes, $E_r$ is residual energy of node h, $\overline{d}$ is average distance between member nodes and base station, $d\left(h, BS\right)$ is the distance between node h and base station. The node which has minimal $W\left(h\right)$ value are selected as secondary node.

## 6. Inter-cluster Routing

Cluster heads send data to secondary node in each cluster. FOA-UCR uses multi-hop method to transfer data between secondary nodes to balanced energy consumption of nodes, defines the cost function as follow

$$\cos t(j) = \frac{d(i,j)^{\lambda}}{E_j} \tag{31}$$

$d(i,j)$ is the distance between secondary node i and j, $\lambda$ is adjustment factor, $E_j$ is the residual energy of secondary node. The node which has the minimal cost value is selected as relay node.

## 7. Simulation

Simulating this protocol based on MATLAB, compared with LEACH and DEBUC. The simulation parameters are shown in table 1.

Table 1. Simulation parameters

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Area | (200*200)m | $R^{o}_{comp}$ | 87m |
| Number of nodes | 1000 | $a$ | 0.6 |
| Positions of base station | (100,250)m | $b$ | 0.4 |
| Packet size | 4000 bit | $d_0$ | 90 |
| Broadcast packet size | 100 bit | $c$ | 0.5 |
| $E_0$ | 0.2J | Maxgen | 30 |

The protocol analyzes from two aspects:number of alive nodes and residual energy of network, and compared with LEACH and PSO-NUDC. Assumption that if the dead nodes is greater than 30% of nodes, the network will stop working.

As shown in figure 2, test result shows that as round goes on, the first death of FOA-UCR turns up until Round 275, however, the first node dead of LEACH and PSO-NUDC are in Round 47 and 230. Compared with PSO-NUDC, FOA-UCR prolongs network lifetime by 19.6%.Simulation results verify that FOA-UCR protocol has enough ability to protect the node with lowest energy and postpone the time of the first death node so as to prolong the lifetime of the whole network.

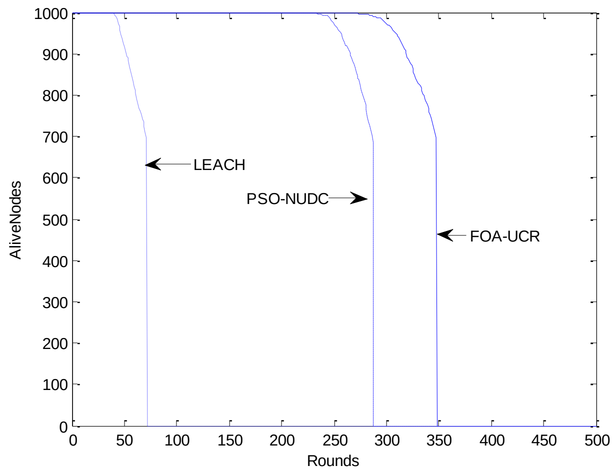


Fig. 2 Number of rounds versus number of alive nodes

In figure 3, it is observed that FOA-UCR protocol has more residual energy than LEACH and PSO-NUDC. Curve slope is smaller and lifetime is longer. FOA-UCR protocol consume less energy than other protocols.

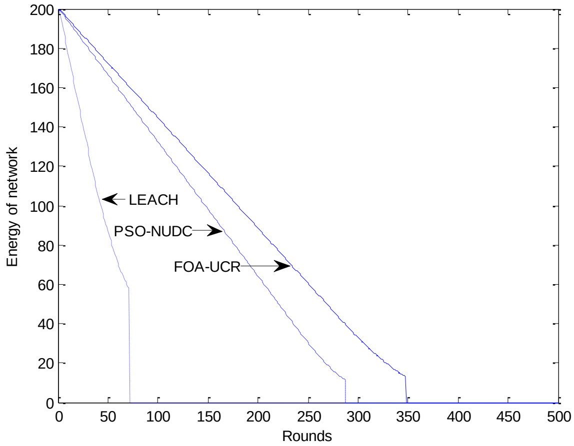


Fig. 3 Number of rounds versus residual energy of network

## 8. Conclusion

This paper proposed an uneven clustering routing protocol in wireless sensor networks, uses fruit fly optimal algorithm to select cluster heads and selects secondary node to cooperate with cluster heads to transfer data to base station. Secondary nodes are responsible for the communication with base station or other secondary nodes. In order to build an optimal path to base station, FOA-UCR protocol utilizes cost function to select the next hop. The experimental results show that FOA-UCR protocol can effectively save nodes' energy and prolong the network lifetime . In order to make the FOA-UCR protocol has a better application effect, the data fusion technology should be deeply studied in the future, to make FOA-UCR protocol achieve a better effect on the energy consumption.

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