# Cluster Routing Algorithm for Ring Based Wireless Sensor Network Using Particle Swarm And Lion Swarm Optimization

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**Research Article**

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# Cluster Routing Algorithm for Ring Based Wireless Sensor Network Using Particle Swarm And Lion Swarm Optimization

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## Abstract:

In order to solve the problem of hot spot caused by uneven energy consumption of nodes in Wireless Sensor Networks (WSNs) and reduce the network energy consumption, a novel cluster routing algorithm called CRPL for ring based wireless sensor networks using Particle Swarm Optimization (PSO) and Lion Swarm Optimization (LSO) is proposed in this paper. In CRPL, the optimal cluster head (CH) of each ring are selected by using LSO whose fitness function is composed of energy,number of neighbor nodes, number of cluster heads and distance. Moreover, PSO with a multi-objective fitness function considering distance, energy and cluster size is used to find the next hop relay node in the process of data transmission, and the optimal routing paths are obtained, so as to alleviate the hot spot problem as well as decrease the energy consumption in the routing process. The simulation results show that, compared with some existing optimization algorithms, CRPL has better effects in balancing the energy consumption of the network and prolonging the life cycle of the network.

**Keywords:** Particle Swarm Optimization   Lion Swarm Optimization   Cluster routing   Multi-objective fitness function

## 1 Introduction

In recent years, with the advent of the era of artificial intelligence, WSN has played an important role in environmental observation, military affairs, building monitoring, medical care, home furnishing, etc[1-3]. However, the development of WSN is still limited by many factors. For example, the sensor nodes that make up a WSN are usually deployed in areas that are difficult or impossible for humans to operate[4], the energy of sensor nodes is limited and cannot be supplemented in time[5], the distribution of sensor nodes is random, resulting in different topological structures of sensor networks, the deployment structure of sensor nodes is very large.Many nodes far away from the Base Station(BS) consume a lot of energy when sending information to the base station, which will cause them to die prematurely and make the information received by the base station incomplete[6,7].

In order to solve the above problems to a certain extent, which improves the service life of WSN, in this paper, a clustering routing algorithm based on PSO and LSO is proposed to balance the network energy consumption and prolong the network life cycle. This algorithm is mainly based on the LSO algorithm, which selects the best Cluster Head(CH) of each ring by using the objective function of four factors: the

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energy of the sensor node, the distance between the node and the BS, the number of neighbor nodes covered in the communication range of a sensor node, and the proportion of CH in the ring. In addition, PSO algorithm is used to establish an improved fitness function based on the distance between CH and BS, the number of cluster member (CM) nodes, the residual energy of CH node in the next hop and the distance between CH and the vertical section of the current CH and BS in the next hop to determine the optimal routing path of data transmission, It also greatly extends the life cycle of the network.

The content of this article is organized as follows: The related works are discussed in Section 2, and the system model is described in Section 3. In Section 4, the proposed CRPL is introduced in detail. In Section 5, simulations are performed and results are analyzed in sequence. Finally,a summary of the whole paper is provided in Section 6

## 2 Related works

At present, clustering routing algorithm is considered to be one of the most effective methods to improve the service life of WSN[8]. Leach [9] is the first clustering routing algorithm. Its main idea is to let nodes act as CHs in turn. LEACH algorithm can avoid the situation that some nodes consume too much energy because they directly transmit information to the BS. However, energy is not taken into account in the selection of CHs, which will lead to the unbalanced load of each cluster in the network. The Leach-C algorithm proposed in [10] takes the nodes whose residual energy value is greater than the average energy value as candidate cluster head nodes, then the CHs with smaller objective function is selected by simulated annealing algorithm, but the location of CHs is not considered in Leach-C. In the distributed energy efficient clustering (DEEC) algorithm proposed in [11], the threshold setting method for selecting cluster heads is the same as LEACH algorithm. Different from LEACH algorithm, the residual energy of nodes and average energy of network are introduced into the probability equation in this algorithm. However, in DEEC algorithm, the cluster head nodes far away from the base station will consume too much energy. In [12] Cluster-Head restricted energy efficient protocol (CREEP) is proposed ,which is a improved protocol basd on DEEC algorithm. First, the influence of residual energy of nodes is considered when setting threshold formula. Secondly, the distance component is introduced into the probability equation to reduce the probability that the node far away from the base station becomes the cluster head, but the cluster size is not considered, which will lead to excessive load and premature death of the CH.

CH election in WSNs is affected by many parameters, and fuzzy control is widely used in multi parameter control model[13]. LEACH-FL proposed in [14] inputs the remaining energy of nodes, the density of nodes and the distance of base station from nodes into the designed fuzzy system for logical inference, and obtains a fuzzification function for the possibility of cluster head selection. Then, the fuzzification function is solved by the moment center algorithm to get specific values as the basis for cluster head selection. In [15] presents a clustering routing protocol which combines Fuzzy C Mean (FCM) with Fuzzy Control (FLS). The FCM algorithm computes the Euclidean distance between nodes to cluster one by one to get the optimal clustering result and the cluster center. After clustering, FLS is executed on each cluster to select the cluster head. In the FLS algorithm, the fuzzy logic system is set up with three factors as the fuzzy input variables: the relative residual energy of nodes, the distance from the cluster center and the distance from the base station. Although fuzzy control can implement multiparameter control variables, its excessive dependence on experience lacks corresponding theoretical basis.

With the development of biomimetic swarm intelligence optimization algorithms, such as Lion Swarm Optimization (LSO), Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Artificial Bee Swarm (ABC), Ant Colony Optimization (ACO), Dragonfly (DA), Elephant Swarm Optimization (EHO), Cuckoo Search (CS) are widely used in clustering routing of WSNs[16-19]. The core of the Lion Group Optimization Algorithm (LSO) is to obtain the optimal value of the objective function through repeated searches. In [20] proposed the lion cluster routing protocol (MOFPL) uses multi-objective fitness functions based on energy, delay, traffic rate, distance and cluster density to select the best CH node. A hybrid optimization algorithm combining lion swarm algorithm and fractional calculus is presented in [21]. The selection of optimal CH in this algorithm mainly refers to several influencing factors, such as intra cluster distance, inter cluster distance, residual node energy and delay. In [22], a multi-objective fractional artificial bee colony hybrid optimization algorithm is proposed, which selects the best cluster head by considering the multi-objective function based on energy consumption, driving distance and delay. In [23] proposed the optimized clustering based on genetic algorithm (GAOC) establishes the fitness function of cluster head election based on residual energy, base station distance and node density. In addition, elitism algorithm is introduced to optimize the genetic algorithm, but too many elites will cause local convergence of the algorithm.

Although the above mentioned algorithms have some effect in alleviating the energy "hot spot" problem and prolonging the life cycle of the network, a large amount of energy consumption is ignored in the routing process, which will cause its effect not obvious. Similarly, there are many optimization algorithms for the routing process. In the routing process, cluster heads can cooperate with each other to forward their data to the base station through multi hop mode[24]. The A GA-based clustering and routing algorithm (GACR) proposed in [25] applies genetic algorithm to routing, and establishes a routing fitness function based on total transmission distance and cluster head hops. This algorithm can save the energy consumed in the routing process, but it is very likely to choose the cluster head with less energy as the relay node. In [26] is proposed the routing protocol based on particle swarm optimization (PSO),which considers not only the number of relay nodes and the distance between CH and BS, but also the relay load factor. However, when a relay node is overloaded, CH may choose a longer alternative path, Thus the energy consumption of CH is increased. In the ant colony optimization algorithm proposed in [27], not only the best routing direction from CH node to BS is considered, but also the distance band, search angle and distance factor are comprehensively considered when looking for the next hop ch node, and the incentive strategy is introduced to balance the "hot" nodes with heavy load to optimize the routing path. However, there may be several similar routing paths from CH nodes to BS in the network, which leads to the problems of fast energy consumption of some nodes or low activity of some nodes.

In [28] proposes to adopt a ring wireless sensor network model, which implements multi-hop communication between cluster head nodes by means of ring splitting. Except for the first ring, each ring cluster head node sequentially searches for relay nodes in the next ring. Then the best routing path of CH can be found through the ring structure; In [29] proposed an Annulus-based energy balanced data collection (AEBDC) method. This algorithm proposes to transmit data with the help of candidate cluster heads to reduce the load of CHs. However, during the data transmission process, the networkThe ring needs more candidate cluster heads to forward data, which increases the energy consumed by candidate cluster head nodes to forward data. The

CAMP routing proposed in [30] divides the non-cluster head nodes in the network area into two types. The two different types of non-cluster head nodes forward their data to the next hop node according to different working constraints. This algorithm achieves the balance of node energy consumption, but divides the non cluster nodes into two categories, which increases the complexity of the network. In order to solve the problems in the above algorithm to a certain extent, this paper proposes a cluster routing algorithm for ring wireless sensor network based on particle swarm and lion swarm to balance network energy consumption and prolong the life cycle of the network. In this paper, a clustering routing algorithm based on particle swarm optimization and lion swarm is proposed to balance the network energy consumption and prolong the network life cycle.

## 3 System model

### 3.1. Network Model

The wireless sensor network model proposed in this paper is shown in Figure 1. The network model is a ring area with a radius of R, in which N sensor nodes are randomly distributed throughout the ring area;The annular region is divided into n concentric rings with the same width, BS is located at the center of the ring. The regional environment of the entire ring network is assumed as follows:

- After the sensor node is deployed, the position of the node in the network will no longer change, and the BS will broadcast its position information to each sensor node in the network;
- · BS will broadcast its position information to each sensor node in the network;
- · The whole network is isomorphic, and each sensor node has a unique ID;
- · Each sensor node has the same initial energy and the same communication radius ;
- · Only allow CH to communicate directly with BS.

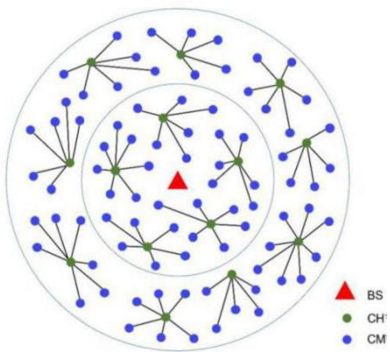



**Fig 1**. Schematic diagram of network model.

### 3.2 Energy Model

The energy consumption in WSN mainly includes the energy consumed by CM node sending data message information to CH in cluster, the energy consumed by CH receiving CM node sending data information, the energy consumed by ch node fusing the message sent by CM node and forwarding it to BS through multi-hop mode, and the energy consumed by CH forwarding the data information of previous hop

CH. The above energy consumption is mainly manifested in the receiving and sending process of sensor nodes. From the energy model in [20], it can be seen that when the distance between the sending node and the receiving node is longer, more energy will be consumed in the process of data transmission. Assuming that the energy consumed by the i-th CM node in the a ring in the network area to transmit data to the j-th CH node in the corresponding ring is $E_c(S_a^i)$, the expression is shown in formula (1):

$$E_c(S_a^i) = \begin{cases} E_e \times m + \varepsilon_{fs} \times m \times ||S_a^i - CH_a^j||^2, & ||S_a^i - CH_a^j|| < d_0 \\ E_e \times m + \varepsilon_{mp} \times m \times ||S_a^i - CH_a^j||^4, & ||S_a^i - CH_a^j|| \geq d_0 \end{cases} \tag{1}$$

Where $E_e$ is the energy consumption of electronic circuit in wireless sensor network, which can be expressed by formula (2). m is the size of the packet sent or received by the sensor node, $\varepsilon_{fs}$ is the amplification parameter when the free space model is used, and $\varepsilon_{mp}$ is the amplification parameter when the multi-channel attenuation model is used[31]. The distance threshold $d_0$ from CM node to ch node is shown in formula (3).

$$E_e = E_{tx} + E_{da} \tag{2}$$

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{3}$$

$E_{tx}$ represents the energy required for the sensor node to transmit data, $E_{da}$ represents the energy required for the sensor node to fuse data.

$E_c(CH_a^j)$ represents the energy consumed by the j-th ch node in ring a to receive m bit data, and its expression is shown in formula (4).

$$E_c(CH_a^j) = E_e \times m \tag{4}$$

After the CM node and CH node in the network send or receive data, they update the energy according to formula (5) and formula (6).

$$E_{t+1}(S_a^i) = E_t(S_a^i) - E_c(S_a^i) \tag{5}$$

$$E_{t+1}(CH_a^j) = E_t(CH_a^j) - E_c(CH_a^j) \tag{6}$$

Among them, $E_{t+1}(S_a^i)$ represents the update energy of the i-th CM node in the a ring, $E_t(S_a^i)$ represents the energy of the i-th CM node in the a ring at time t, $E_c(S_a^i)$ is the energy consumed by the i-th CM node in ring a before time t, $E_{t+1}(CH_a^j)$ is the update energy of the j-th CH in ring a, $E_t(CH_a^j)$ is the energy of the j-th CH in a ring at time t, and $E_c(CH_a^j)$ is the energy consumed by the j-th CH in a ring before time t.

## 4 The proposed CRPL algorithm

Figure 2 shows the flow structure diagram of the CRPL algorithm proposed in this paper. The CRPL algorithm uses the LSO algorithm to select the optimal CH of each ring in the network during the setup phase and uses the improved PSO algorithm to find the best routing path for network data transmission in the steady state phase. The following are the advantages of the CRPL algorithm proposed in this paper.

- · Using LSO and PSO algorithms to optimize the selection of CH nodes and routing paths, not only speeds up the convergence speed, reduces energy consumption, and is more targeted;
- · A fitness objective function based on multiple factors is used to optimize CH and routing paths, so that the selection of CH and the determination of the best path are more global;
- · This paper uses the LSO algorithm to find the optimal CH in the network, which provides convenience for finding the optimal path and speeds up the path search speed.

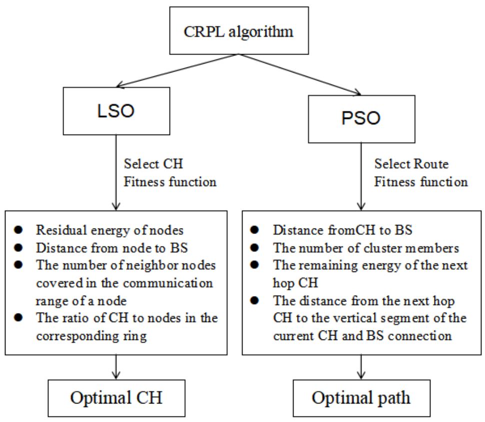



**Fig 2.** Flow chart of CRPL algorithm

## 4.1 Selection of CH

### 4.1.1. Brief introduction of LSO

This paper mainly bases on the territorial defense and territorial takeover of the lion group in [32] to find the CH of each ring in the network. In the LSO algorithm, lions are divided into two categories: territorial lions $T$ and nomadic lions$Y^m$, of which territorial lions are further divided into male territories and female territories. It is the main task of the male territory lions to prevent the nomadic lions from invading the lions, and to mate with the female territory lions to give birth to the next generation of cubs. Nomadic lions become new territory lions after they expel or kill territory lions and cubs. This behavior of nomadic lions increases the global optimization of LSO. This article assumes that the sensor node in the wireless sensor network is the lion in the lion group, and three nodes are randomly selected from the network to represent the male lion $T^m$, the female land lion $T^f$ and the nomadic lion $Y^m$ in the lion group. The fitness functions are $V^m$、$V^f$ and $V^Y$, and the fitness function of the common territories lion is used as the reference value of the fitness value. At the same time, the fertility of female territory lion was evaluated according to formula (7).

$$T_q^f = \begin{cases} T_j^f, & q = j \\ T_q^f, & q \neq j \end{cases} \tag{7}$$

$$T_j^v = \min[T_q^{max}, \max(T_j^{min}, \nabla_j)] \tag{8}$$

Where, $T_q^f$ and $T_j^f$ represent the i-th and j-th female territory lion respectively, formula (8) is the boundary condition, and $\nabla_j$ represents the update function of female territory lion.

$$\nabla_j = [T_j^v(t) + (0.1r_2 - 0.05)(T_j^v(t) - r_1 T_j^v(t))] \tag{9}$$

Where $r_1$ and $r_2$ are random numbers between 0 and 1. The female territory lion completes the update according to formula (9). Due to the problems of crossover, mutation, and gender differences in cubs due to mating between female and male land lions, it is necessary to kill the weak and more sexual cubs in order to maintain the balance of the lion group and realize the regeneration of the whole lion group. At the same time, when defending the territory between the nomadic lion and the territory lion, the lion with the highest fitness value is selected as the new territory lion to realize the regeneration of the lion group. When the cubs mature, the mature male cubs take over the territory and become a new territory lion. These updating behaviors of the lion group until the maximum iteration period required by the lion group is reached.

### 4.1.2. CH election fitness function

The choice of CH directly affects the energy balance of the network, and also determines the efficiency of data transmission in the network. This paper adopts the four factors proposed in formula (10) based on the remaining energy of the node, the distance from the node to the BS, the proportion of the CH node in the ring, and the number of neighbor nodes covered by the node's communication range to select the CH in the network. The CH selected in the network should meet the maximum value provided by the fitness function, and the fitness function is expressed as follows.

$$F_c = \alpha \times E_{ae}^i + \beta \times d_{ab}^i + \gamma \times C_a + \mu \times n_n^i \tag{9}$$

Where $E_{ae}^i$ is the ratio of the residual energy $E_{ac}^i$ and the initial energy $E_o^i$ of the i-th node in ring a of the network, $d_{ab}^i$ is the ratio of the distance $d_{ib}^i$ from the inner ring boundary to BS and the distance $d_{ab}^i$ from the node to BS, $C_a$ is the ratio of the optimal number of CH nodes $n_a^c$ in a ring to the number of nodes $n_a$ in the corresponding ring, ($1 \le i \le c_a^{\max}$, $1 \le a \le n$, where $c_a^{\max}$ is the maximum number of nodes per ring). The values of α 、 β 、 γ and μ are constants between 0 and 1, and $\alpha + \beta + \gamma + \mu = 1$. The expressions of $E_{ae}^i$, $d_{ab}^i$, $C_a$ and $n_n^i$ are formula (11-14) .

$$E_{ae}^i = \frac{E_{ac}^i}{E_o^i} \tag{11}$$

$$d_{ab}^i = \frac{d_{ib}^i}{d_{ab}^i} \tag{12}$$

$$C_a = \frac{n_a^c}{n_a} \tag{13}$$

$$n_n^i = \frac{n_{an}^i}{n_a} \tag{14}$$

## 4.2 Routing path selection

### 4.2.1. Brief introduction of PSO

The PSO algorithm[33, 34] is derived from the study of bird foraging behavior. It is a global search algorithm, which formulates optimization rules for each particle. Suppose that in a D-dimensional solution space, there are N particles, each particle has the same size, and the D-dimensional vector expression of the i-th particle $S_i$ is formula (15).

$$S_i = (x_{i1}, x_{i2}, x_{i2}, \dots, x_{iD}), \quad i = 1,2,\dots,N \tag{15}$$

Each particle has an initial position and initial velocity, and the velocity $V_{i,k}(t)$ and position $X_{i,k}(t)$ of particle $S_i$ are updated according to formulas (16) and (17).At the same time, the fitness value $F_{fit}(S_i)$ of the updated particle is calculated.

$$V_{i,k}(t+1) = w \times V_{i,k}(t) + c_1 \times r_1 \times \left(pbest_{i,k} - V_{i,k}(t)\right) + c_2 \times r_2 \times \left(Gbest_k - V_{i,k}(t)\right) \tag{16}$$

$$X_{i,k}(t+1) = X_{i,k}(t) - V_{i,k}(t) \tag{17}$$

Where $c_1$ and $c_2$ are acceleration constants and $r_1$ and $r_2$ are random numbers between [0,1]. $V_{i,k}(t+1)$ is the update speed of particle $S_i$, $X_{i,k}(t+1)$ is the updated position of particle $S_i$ $\{ i = 1,2,\dots,N, k = 1,2,\dots,D\}$. $w$ is the inertia weight of the particle. When $w \in (0.8\sim1.2)$, the particle swarm algorithm has a faster convergence speed. In this paper, the expression is shown in (18):

$$w = w_{max} - \frac{(w_{max} - w_{min}) \times t}{T_{max}} \tag{18}$$

$pbest_i$ is the best position searched by a particle $S_i$ so far, that is, the individual extreme value, and $Gbest_k$ is the best position searched by particle swarm so far, that is, the global extreme value. After obtaining the new update position and speed, in order to find the optimal solution particle and the global optimal solution particle in the particle iteration process, the fitness value $F_{fit}(S_i)$ of particle $S_i$ is compared with the individual extreme value $pbest_i$ and the global extreme value $Gbest_k$ until the appropriate or $Gbest_k$ reaches the maximum number of iterations $T_{max}$. The update formulas for $pbest_i$ and $Gbest_k$ are as follows.

$$pbest_i = \begin{Bmatrix} S_i, if\,(F_{fit}(S_i)\ \pi\ F_{fit}(pbest_i)) \\ pbest_i, \quad Others \end{Bmatrix} \tag{19}$$

$$Gbest = \begin{Bmatrix} S_i, if\,(F_{fit}(S_i)\ \pi\ F_{fit}(Gbest)) \\ Gbest\ , \quad Others \end{Bmatrix} \tag{20}$$

### 4.2.2. Route selection fitness function $F_R$

The core idea of routing optimization is to find the best relay node in the data transmission stage. This paper proposes a fitness function based on four factors: the distance between CH and BS, the number of cluster member nodes, the residual energy of next hop CH and the distance between next hop CH and the vertical segment of the current CH connecting with BS. The optimal routing path satisfies the minimum value provided by the fitness function, and the fitness function is expressed as formula (21).

$$F_R = u_1 \times d_{c-nc} + u_2 \times C_{cm-ccm} + u_3 \times d_{c-cB} + u_4 \times E_{next-c} \tag{21}$$

Assuming that the current CH is located in the a ring in the network, and the communication between all nodes is within the communication radius $r_c$ of the node, $d_{c-nc}$ denotes the ratio of the distance $d^a_{c-c}$ from the k-th CH $CH^a_k$ in a ring to the k-th CH $CH^{a-1}_p$ in (a-1) ring to the distance $d^a_{c-B}$ from the k-th CH $CH^a_k$ in a ring to BS.It is expressed as formula (22).

$$d_{c-nc} = \frac{d^a_{c-c}}{d^a_{c-B}} \tag{22}$$

When the cluster where a CH is located is smaller, the number of CM nodes is smaller, and the data transmission delay of this cluster is smaller. $C_{cm-ccm}$ is the ratio of the number of CM nodes $C^{a-cm}_k$ in the cluster where the CH $CH^a_k$ is located to the number of all CM nodes $C^{a-cm}_{all}$ in ring a. It is expression as formula (23).

$$C_{cm-ccm} = \frac{C^{a-cm}_k}{C^{a-cm}_{all}} \tag{23}$$

$d_{c-cB}$ is the ratio of the distance $d_{c-c}$ between the p-th CH $CH^{a-1}_p$ in ring $(a-1)$ and the vertical segment of the connection line between the k-th CH $CH^a_k$ and BS in ring a to the distance $d^a_{c-B}$ between the k-th CH $CH^a_k$ and BS. As shown in Figure 3, when $d_{c-c}$ is smaller, the routing path of $CH^a_k$ nodes forwarding data to BS through relay node is closer to $d^a_{c-B}$. According to the shortest straight line between the two points, it can be seen that the less energy is consumed for data transmission at this time, which balances the energy consumption of the network. Where BS coordinate is $(x_0, y_0)$, $CH^{a-1}_p$ coordinate is $(x^{a-1}_p, y^{a-1}_p)$, $CH^a_k$ coordinate is $(x^{a-1}_k, y^{a-1}_p)$, then $d_{c-c} = \frac{|(y_0 - y^a_k)\times(x^{a-1}_p - x^a_k) + (y^a_k - y^{a-1}_p)\times(x_0 - x^a_k)|}{\sqrt{(y_0 - y^a_k)^2 + (x_0 - x^a_k)^2}}$, $d^a_{c-B} = ||BS - CH^a_k||$, $d_{c-cB}$expression such as formula (24).

$$d_{c-cB} = \frac{d_{c-c}}{d^a_{c-B}} \tag{24}$$

$E_{next-c}$ can be expressed as the ratio of the current residual energy $E^{a-1}_c$ of the c-th CH in $(a-1)$ ring to its initial energy $E_o$,The expression is formula (25).

$$E_{next-c} = \frac{E^{a-1}_c}{E_o} \tag{25}$$

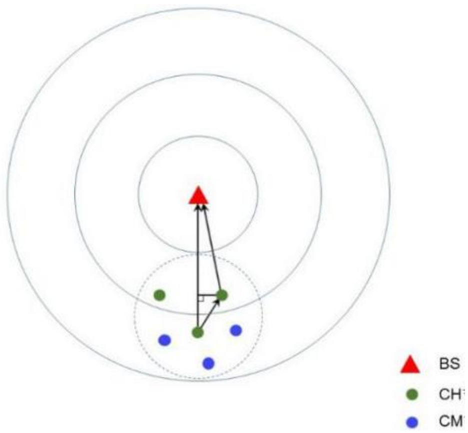



**Fig3.** The best route selection road map

In the data transmission process, the CH in the first ring communicates directly with the BS, while the CH in other rings needs to be forwarded by the CH (namely relay node) in the next ring to communicate with the BS. The best routing path depends on the selection of relay nodes. When selecting relay nodes, the improved PSO algorithm fitness function is used to find the best path. The CH with short distance to BS, less cluster members and more residual energy is selected as the relay node. At the same time, the relay node should be close to the connection between the current CH and BS as far as possible to reduce the energy consumption caused by long transmission distance in the process of data transmission.

## 5 Performance evaluation

The CRPL algorithm proposed is a simulation experiment in MATLAB 2019a, which is mainly carried out in the ring network area with the sensing area of 400 * 400m and 600 * 600m. Through a large number of experiments and analysis, the simulation results of four performance indicators of CRPL algorithm are obtained: network survival node, network energy consumption, network throughput and network residual energy. The simulation results are compared with the classic clustering algorithm LEACH proposed in [9], the FCM-FSL algorithm proposed in [15] and the PSO routing algorithm proposed in [26]. The setting of simulation experiment environment parameters is shown in Table 1.

**Table 1** Simulation parameter settings

| Parameters | Scenario 1 | Scenario 2 |
|---|---|---|
| Number of nodes | 100,200 | 100,200 |
| Initial energy | 5J | 5J |
| $E_{elec}$ | 50 (nJ/bit) | 50 (nJ/bit) |
| $\varepsilon_{fs}$ | 10 (pJ/bit/m$^2$) | 10 (pJ/bit/m$^2$) |
| $\varepsilon_{mp}$ | 0.0013 ((pJ/bit/m$^4$) | 0.0013 ((pJ/bit/m$^4$) |

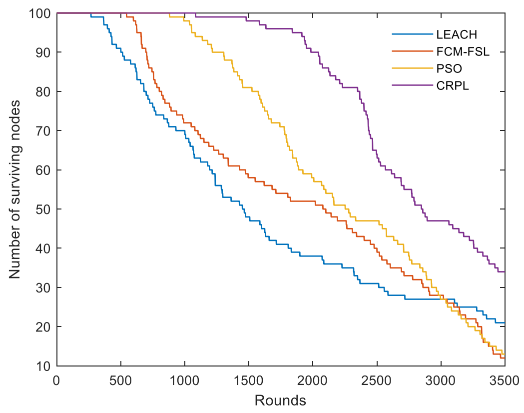
| | | |
|---|---|---|
| Data packet size | 4000bits | 4000bits |
| Control packet size | 200bits | 200bits |
| Area | 400m*400m | 600m*600m |
| BS Location | x=200,y=200 | x=300,y=300 |

## 5.1 Analysis of network surviving nodes

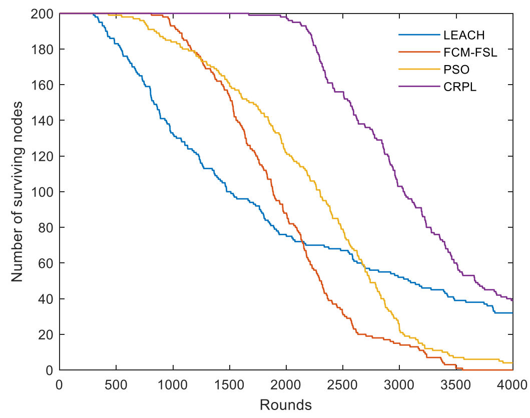
The life cycle of a network is related to the number of surviving nodes in the current network round. Corresponding to the number of surviving nodes in the network is the number of deaths of network nodes. Therefore, the number of death rounds of the first node in the network and the number of death rounds of half of the nodes are the best measure of the life cycle of the network. The simulation results are shown in Table 2. The change in the number of surviving nodes is shown in Figure 4.

**Table 2.** This is a table. FND and HND in different Scenarios

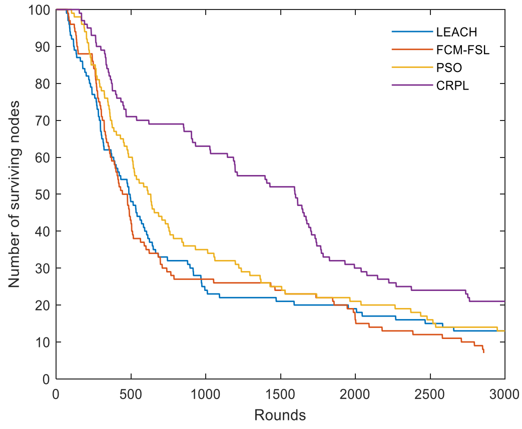
| Items \ Algorithms | | | LEACH | FCM-FSL | PSO | CRPL |
|---|---|---|---|---|---|---|
| Scenario #1 | Case 1: 100 nodes | FND | 267 | 545 | 880 | 1085 |
| | | HND | 1464 | 2101 | 2280 | 2858 |
| | Case 2: 200 nodes | FND | 298 | 692 | 432 | 1669 |
| | | HND | 1511 | 2075 | 2299 | 3041 |
| Scenario #2 | Case 1: 100 nodes | FND | 68 | 76 | 102 | 168 |
| | | HND | 494 | 476 | 632 | 955 |
| | Case 2: 200 nodes | FND | 60 | 96 | 38 | 209 |
| | | HND | 393 | 359 | 998 | 1495 |



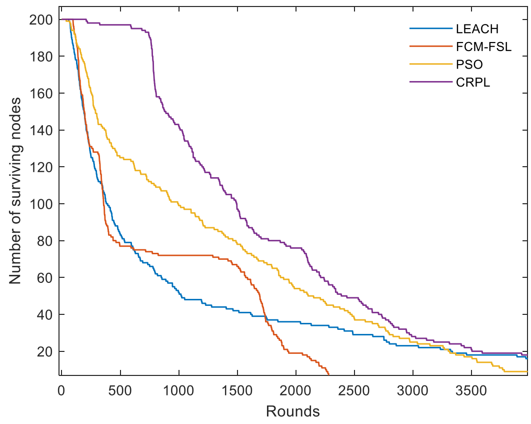

(**a**)The number of alive nodes in Scenario #1 with 100 nodes




(**b**)The number of alive nodes in Scenario #1 with 200 nodes




(**c**)The number of alive nodes in Scenario #2 with 100 nod



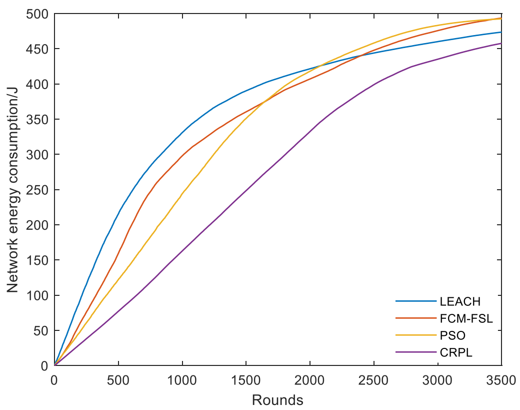

(**d**)The number of alive nodes in Scenario #2 with 200 nodes

**Fig 4.** Comparison of the network lifetime

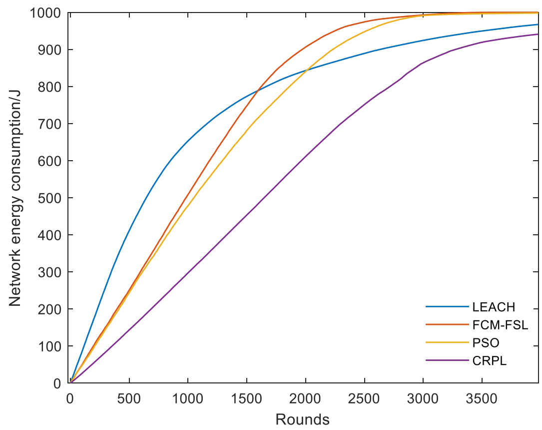
As can be seen from Figure 4, at the beginning of the network operation, the number of surviving nodes in the network remains unchanged. However, due to the different working principles of the CRPL algorithm, LEACH algorithm, FCM-FSL algorithm, and PSO routing algorithm, the workload of the nodes in the network is different, which causes the nodes to begin to die in different rounds of CH. According to the data in Table 1, it can be seen that the first node death in the LEACH algorithm network in Scenario # 1 and Scenario # 2 occurred in 267, 298, 68 and 60 rounds, respectively. When FCM-FSL runs 545, 692, 76 and 96 rounds respectively, the first node dies. PSO routing algorithm and CRPL algorithm adopt multi hop communication protocol.In the simulation results, the first node death rounds of PSO algorithm appear in 880, 432, 102 and 83 rounds respectively.The CRPL algorithm's first node death rounds appeared in 1085, 1669, 168, and 209 rounds,the simulation results of CRPL are 75.30%, 82.14%, 59.52% and 71.29% higher than leach, 49.77%, 58.54%, 54.76% and 54.07% higher than fcm-fsl, and 18.89%, 74.12%, 39.29% and 60.29% higher than PSO. At the same time, it can be seen from Figure 4 that the curve of the number of surviving nodes in CRPL network is always above the curve of LEACH algorithm, FCM-FSL algorithm and PSO routing algorithm. This also can show that CRPL algorithm has a longer life cycle.

## 5.2Analysis of network energy consumption

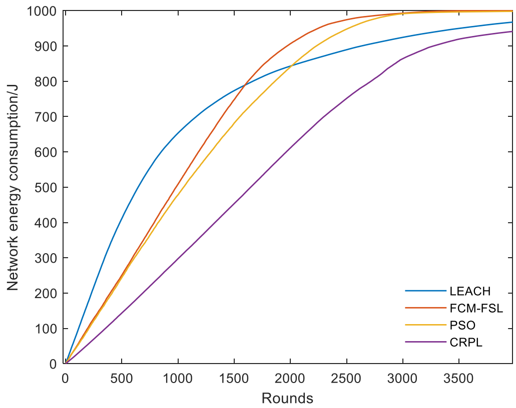
The life cycle of a network is also inversely proportional to the total energy consumption of the network. The change of the total energy consumption of the network is shown in Figure 5.



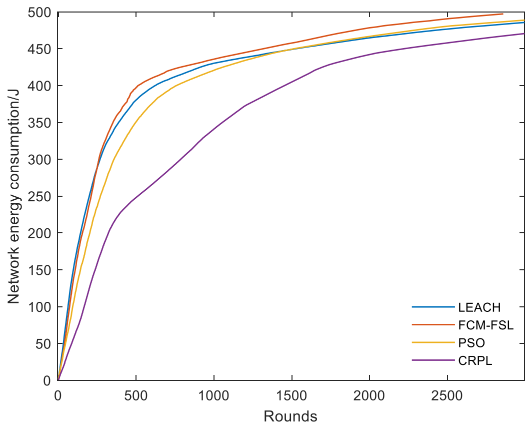

(**a**)Energy consumption in Scenario #1 with 100 nodes




(**b**) Energy consumption in Scenario #1 with 200 nodes




(**c**)Energy consumption in Scenario #2 with 100 nodes



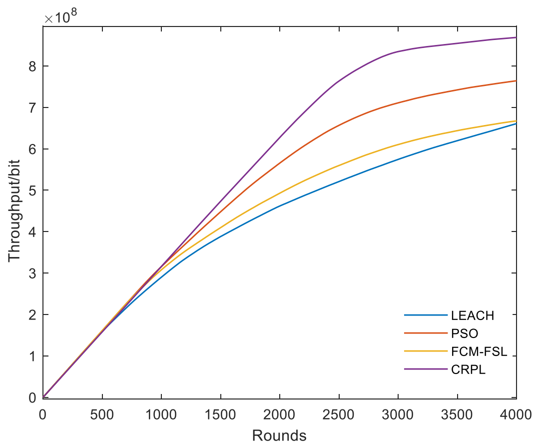

(**d**)Energy consumption in Scenario #2 with 200 nodes

**Fig 5.** Comparison of the total energy consumption versus rounds

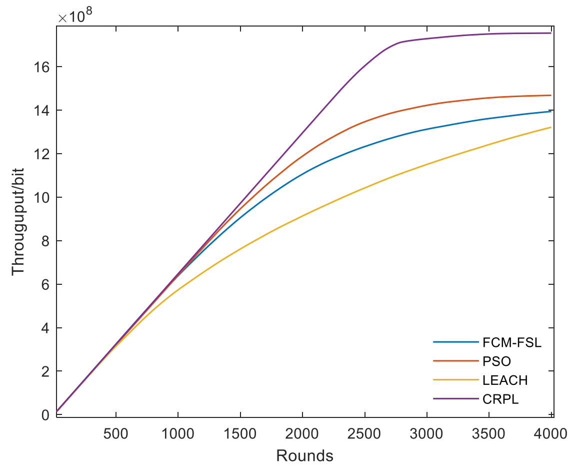
It can be seen from Figure 5 that with the increase in the number of CH rotations in the network, the network energy consumption continues to increase. The total network energy consumption curve of LEACH, FCM-FSL and PSO algorithms is always above the total energy consumption curve of the CRPL algorithm network. In Scenario # 1 and Scenario # 2, the network energy consumption of LEACH algorithm reaches 50% at 615, 645, 199 and 164 rounds respectively, FCM-FSL algorithm network energy consumption reaches 50% in 763, 996, 212, and 166 rounds respectively, PSO algorithm reaches 50% when the number of CH rotation rounds reaches 1028, 1052, 270, and 264 rounds respectively,while that of CRPL algorithm reaches 50% when the number of CH rounds reaches 1509, 1649, 514 and 737 respectively. It can be seen that compared with LEACH algorithm, FCM-FSL algorithm and PSO algorithm, CRPL algorithm has more obvious advantages in saving network energy consumption.

## 5.3 Analysis of network throughput

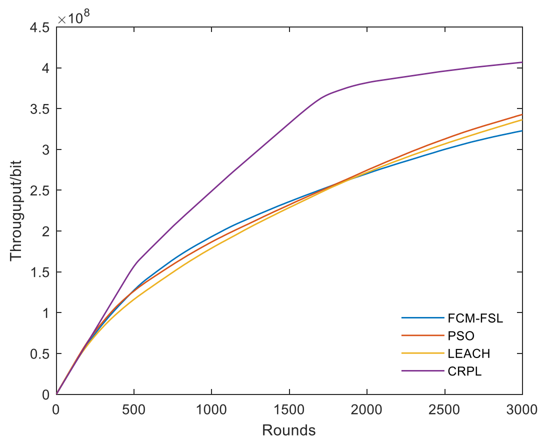
The total network throughput represents the total amount of data transmitted from the network to the base station. Figure 6 shows the change of network throughput in the simulation of Scenario # 1 and Scenario # 2.



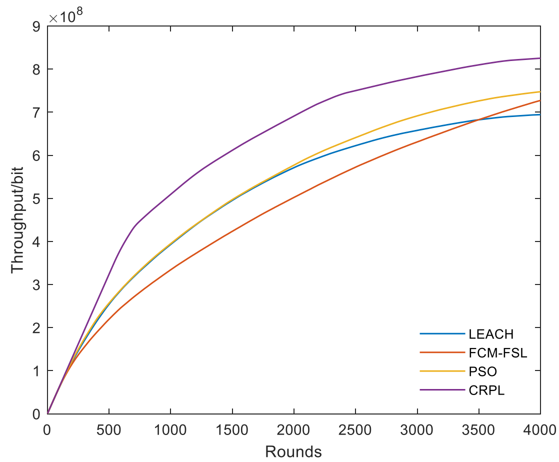

(**a**)The network throughput in Scenario #1 with 100 nodes




(**b**)The network throughput in Scenario #1 with 200 node




(**c**)The network throughput in Scenario #2 with 100 nodes



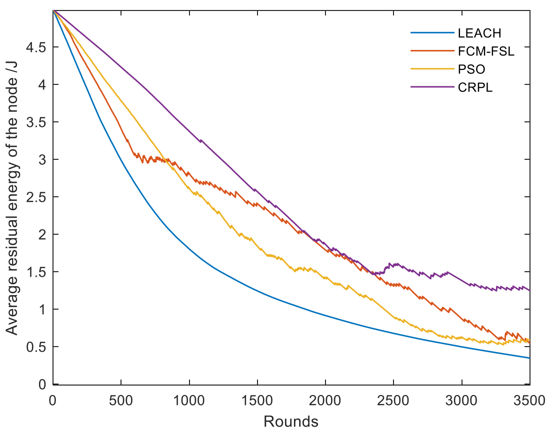

(**d**)The network throughput in Scenario #2 with 200 nodes

**Fig 6.** Comparison of the network throughput versus rounds

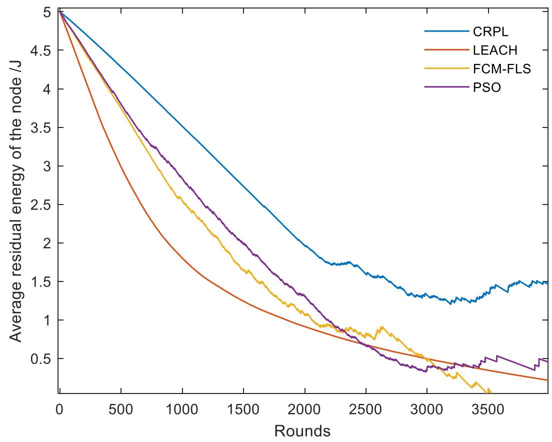
It can be seen from Figure 6 that for all protocols, their network throughput increases with the number of rounds of simulation run. In addition, in the network throughput simulation results of Scenario # 1 and Scenario # 2, compared with LEACH, FCM-FSL and PSO, CRPL has the highest network throughput. CRPL is 23.94%, 24.67%, 8.3% and 15.87% higher than Leach, 23.18%, 20.54%, 12.0% and 11.87% higher than FCM-FSL, 12.03%, 16.31%, 6.56% and 9.43% higher than PSO. This simulation result shows that the CRPL algorithm not only effectively saves energy consumption, but also ensures the amount of data transmitted over the network.

## 5.4 Analysis of residual energy

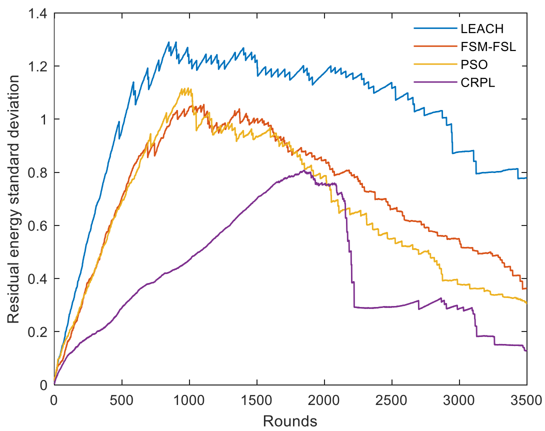
The remaining energy of the network is a key indicator to measure the network life cycle and network energy consumption, and the balance of network energy consumption can be further measured by its mean and standard deviation. Figure 7 (a) and (b) are graphs of changes in the average residual energy of network nodes, and Figure 7 (c) and (d) are graphs of standard deviation changes of network residual energy.



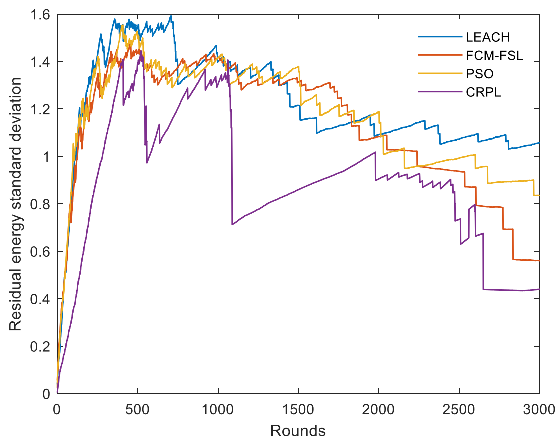

(**a**) Average residual energy of node in Scenario #1 with 100 nodes




(**b**)Average residual energy of node in Scenario #1 with 200 nodes




(**c**)Standard deviation of RE in Scenario #1 with 100 nodes




(**d**)Standard deviation of RE in Scenario #2 with 100 nodes

**Fig 7.** Comparison of the total residual energy versus rounds

Firstly,It can be seen from Figures 7(a) and 7(b) that with the increase of the number of CH rotations, the average remaining energy of the nodes in the network in the CRPL algorithm, LEACH algorithm, FCM-FSL algorithm and PSO algorithm continues to decrease. When the nodes in the network begin to die, the decline of the residual energy curve of the network slows down. It can also be clearly seen from Figure 7 that the average remaining energy curve of the network nodes in the CRPL algorithm is always above the remaining energy curve of the LEACH algorithm, FCM-FSL algorithm, and PSO algorithm. Secondly, it can be seen from Figures 7 (c) and 7 (d) that the standard deviation of residual energy of each round of nodes in network operation is less than that of LEACH algorithm, FCM-FSL algorithm and PSO algorithm, which can further show that CRPL algorithm has certain advantages in balancing network energy consumption.

## 6 Conclusion

The development of swarm intelligence optimization algorithms has brought inspiration for solving some complex distributed problems. At the same time, it is inspired to solve the problems of fast energy consumption and short network life cycle in WSN. The main purpose of this paper is to balance network energy consumption, improve network energy efficiency and prolong network lifetime. For the above purpose, this paper proposes a cluster routing algorithm for ring wireless sensor networks based on PSO and LSO to balance network energy consumption and extend the life cycle of the network. This algorithm mainly elects CH based on LSO algorithm, and uses improved PSO algorithm to select the best routing path in the process of data transmission. Through the analysis of the simulation experiment results, in terms of network life cycle performance, the CRPL algorithm proposed in this paper increases 72.22%, 54.28%, and 48.15% respectively compared with LEACH algorithm, FCM-FSL algorithm and PSO algorithm; in terms of saving network energy consumption, CRPLCompared with LEACH algorithm, FCM-FSL algorithm and PSO algorithm, the algorithm has increased by 60.45%, 51.01%, and 37.69% respectively; in terms of network data throughput, CRPL algorithm has increased by 26.46%, compared with LEACH algorithm, FCM-FSL algorithm and PSO algorithm.30.04%, 27.34%. The simulation experiment analysis shows that the CRPL algorithm has obvious advantages in balancing network energy consumption and extending network life cycle, and has better scalability in networks of different scale.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## Ethics declarations:

**Conflict of interest:** Conflict of interest is not applicable in this work.

**Ethics Approval and Consent to Participate:** No participation of humans takes place in this implementation process.

**Human and Animal Rights:**This article does not contain any studies with human participants or animals performed by any of the authors. No violation of Human and animal rights is involved.

**Informed Consent:** All authors read and approved the final manuscript.

## Authors' contributions:

Conceptualization and Writing - original draft preparation:[Huangshui Hu]; Methodology: [ Yuxin Guo]; Formal analysis and investigation: [ Jinfeng Zhang]; Writing - review and editing: [ Chunhua Yin],Writing - review and editing: [Dong Gao].

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