International Core Journal of Engineering Volume 7 Issue 4, 2021
ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

# Non-uniform Clustering Algorithm for Container IoT in Ocean Transportation Scenarios

Shengnan Zong[a], Yangyang Hao and Lu Zhou

School of Shanghai Maritime University, Shanghai 200135, China.

2819432606@qq.com

## Abstract

**Aiming at the problem that it is difficult to realize the visualization and real-time information of the container Internet of Things in the current ocean transportation process, an improved LEACH non-uniform clustering algorithm is proposed to solve the uneven node energy consumption and the premature death of nodes in the cluster routing algorithm. And other issues, and fully consider the respective characteristics of general-purpose containers and refrigerated containers to make them more in line with the application requirements of the container Internet of Things, and realize the efficient transmission of ocean-going container transportation information. First, in the cluster establishment stage, a reasonable size cluster is constructed through the improved LEACH algorithm and the non-uniform competition radius. Second, in the inter-cluster routing stage, a multi-hop routing method between clusters that approximates the shortest path is designed. Third, in the rotation phase of the cluster head, in order to reduce the number of network reorganizations and reduce energy consumption, an intra-cluster rotation mechanism is adopted. The simulation results show that the improved algorithm is not only suitable for network environments of various scales, but also effectively balances the energy consumption of the container Internet of Things, better solves the problem of premature death of nodes, and prolongs the survival time of the network.**

## Keywords

**Ocean Transportation; Internet of Things; LEACH Algorithm; Non-uniform Clustering; Energy Balance.**

## 1. Introduction

With the rapid growth of domestic and foreign trade, container transportation plays a vital role in global freight transportation with its advantages of speed, safety and low cost. In international trade, the transportation of containers is mainly realized by sea, but a sea transportation usually takes several months. Therefore, if uncomfortable humidity, temperature, smoke, vibration and other environmental factors occur during transportation, the goods will deteriorate. Or damaged. Therefore, the transportation safety issues of containers and their cargo, real-time visual tracking, and convenient information transmission have increasingly become the focus of research in this field[1].

Container Internet of Things is a communication network composed of many wireless communication nodes, which can monitor various information in a certain area, such as temperature, humidity, pressure, etc. The United States put forward the new concept of "smart container" logistics in 1990, and then began to try to use GPS technology to remotely monitor vehicles transporting dangerous goods to ensure the safety of transportation[2]. At present, the container Internet of Things usually relies on 2/3/4G and NB-IOT technologies to achieve networking in land transportation scenarios.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

However, there is no signal in any mobile communication network during the shipping process, which makes it difficult for the existing container Internet of Things applications to play. Real-time monitoring function. Therefore, it is necessary to implement a regional ad hoc network on the ship, collect container information in a unified manner, and realize the connection of sea and land communication through the shipborne satellite network, so as to realize the global operation support of the container Internet of Things[3]. In 2017, the shipping container logistics company under the German third-party logistics company Hellmann Worldwide Logistics announced the application of satellite monitoring systems to container monitoring. The system applies the artificial satellite global monitoring system Secure System developed by the satellite technology development company Astrium under the European Aviation Defense and Space Company (EADS), including communication equipment and sensor detection equipment, which can be detected by installing on the inside of the container door The temperature and humidity in the box, the opening and closing status of the door, etc., the box is locked by the electronic code lock included in the system, which requires authorization to enter, and the opening and closing status of the door lock can be stored and queried, and the data is sent to the artificial Satellite, then forward to the monitoring center, if there is an abnormal situation, it will alarm[4].

At present, although the container Internet of Things has solved the information visualization and real-time problems of the maritime container Internet of Things, the excessive energy consumption and network paralysis of the container Internet of Things still pose hidden dangers to the safety of ocean transportation cargo. Therefore, the primary design goal of the container Internet of Things is to efficiently and evenly use the energy of sensor nodes to extend the network survival time[5].

Containers mainly include general-purpose containers and refrigerated containers. Refrigerated containers transport mostly fresh food, medicines, etc., which require real-time and uninterrupted monitoring of the temperature and humidity in the container, that is, the nodes on the refrigerated container are continuously rechargeable and can be automatically charged when the energy is lower than a certain value. The nodes on the general-purpose container are battery-type nodes with limited initial energy and a large number of containers on board, which can easily cause node death and network pralysis.

The cluster routing algorithm can save energy consumption, avoid network paralysis and information loss. In a sensor network organized in clusters, the cluster head is responsible for the establishment of the cluster structure, collects the data of cluster members, and sends it to the sink node after fusion processing . Long-distance data transmission will easily cause the cluster heads far away from the sink node to consume too much energy. Existing studies have shown that multi-hop communication is beneficial to save energy consumption, but this will lead to uneven energy consumption. The cluster head of a node needs to forward a large amount of data from other clusters and is overburdened, and the energy consumption is too fast to die, which greatly shortens the survival time of the network. Researchers call this problem a "hot spot" problem[6].

For the energy consumption problem of the container Internet of Things, LEACH algorithm is the most classic solution algorithm[7]. The algorithm uses random cluster head selection and periodic cluster head rotation mechanism to divide the entire sensor network into several clusters of equal size. Each node generates a random number rand() between (0,1), compares $rand()$with the threshold function $T(n)$, if the condition $rand() < T(n)$ is met, the node becomes a cluster first. In the data transmission stage, the cluster head transmits the fused data to the sink node in a single-hop communication mode.

$$T(n) = \begin{cases} \frac{p}{1-p(rmod(1/p))}, & n \in G \\ 0, & n \notin G \end{cases} \tag{1}$$

Among them: $p$ represents the proportion of cluster head nodes in the network, $p = 0.1$; $r$ is the current cycle round number; $rmod(1/p)$ is the number of nodes that have not been selected as cluster heads; $G$ is the set of nodes that are not selected as cluster heads after running $1/p$ round.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

In recent years, researchers have proposed a variety of improved algorithms based on LEACH algorithm. The LEACH-C protocol proposed by Mahapatra RP et al.[8] uses the remaining energy of the node and the distance between the node and the base station to form a cluster with lower energy consumption, but does not consider the communication energy consumption between cluster heads. Then came LEACH-K and LEACH-R algorithms[9-11]. Compared with LEACH algorithm, the performance of the improved algorithm has been improved to a certain extent, but it still cannot effectively solve the "hot spot" problem in the network. C.F. Li et al.[12] proposed a multi-hop routing protocol for wireless sensor networks based on non-uniform clustering. Cluster heads are generated through local competition, and non-uniform competition ranges are used to construct clusters of unequal sizes, effectively balancing energy consumption of the cluster head. L. Wang[13] proposed corresponding improvement measures for the threshold setting and the calculation of the non-uniform cluster competition radius in the cluster head competition stage. In the stage of multi-hop routing between clusters, the network energy cost cost formula is used to better solve the "hot spot" problem.M. Li[14] proposed a non-uniform clustering scheme based on the remaining energy and location of cluster head nodes, constructing an objective function suitable for wireless sensor networks, and balancing network energy consumption. Y.L. Pan[15] proposed an energy-efficient wireless sensor network clustering routing algorithm, which improved from the three stages of cluster head selection, cluster head node clustering and data transmission, effectively prolonging the network lifetime.

Compared with the existing research work, the improved algorithm proposed in this paper has the following innovations: (1) The non-uniform clustering algorithm is applied to the container IoT self-organizing network process in the ocean transportation scenario, fully considering the general container (2) Different from LEACH algorithm, the algorithm in this paper is based on node residual energy factor, average residual energy factor of network surviving nodes and neighbor node distribution density factor, setting threshold $T(s_i)$, and improving cluster head election mechanism; (3) Design an energy-balanced routing algorithm for multi-hop data forwarding between cluster heads; (4) Adopt an intra-cluster rotation mechanism during cluster head rotation, taking into account the remaining energy of the new cluster head and the distance to the cluster center , Not only can reduce the frequency of cluster head replacement, save energy consumption, but also reduce the number of cluster head rebuilding.

## 2. System model

### 2.1 Network model

This article is aimed at the container IoT application scenario in the ocean transportation scenario, assuming that N sensor nodes are randomly distributed in the network, and the basic network conditions are assumed as follows:

1) The containers are stacked randomly with a fixed position relationship, and each node on the container has its unique identification number ID.

2) Container types include general-purpose containers and refrigerated containers. Convergence nodes and refrigerated container nodes are rechargeable nodes. General-purpose container network nodes have limited energy and uneven energy levels.

3) The initial energy of the refrigerated container node and the dry cargo container node when the energy is 100% is equal, both are $E_0$.

4) All container nodes have similar processing and communication capabilities, and can calculate the current remaining energy and position information.

5) All sensor nodes can perceive the number of neighbor nodes within their standard communication range and their own remaining energy.

6) The node is not configured with GPS, but in the network initialization phase, the node can calculate the distance between itself and the sink node based on the RSSI value.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

7) The data collected between adjacent nodes in the cluster are independent of each other, and data fusion is not required.

### 2.2 Energy Model

Assuming that each packet has k bit data, the sender consumes:

$$E_T(k,d) = \begin{cases} kE_{elec} + k\varepsilon_{fs}d^2, d < d_0 \\ kE_{elec} + k\varepsilon_{mp}d^4, d \geq d_0 \end{cases} \tag{2}$$

Energy consumed by the sensor node to receive $k\ bit$ data is:

$$E_R(k) = k \cdot E_{elec} \tag{3}$$

Note that $E_{elec}$ is the energy consumption per unit $bit$ data transmitted and received; $\varepsilon_{fs}$ represents the data energy consumption per unit bit in free space mode; $\varepsilon_{mp}$ represents the data energy consumption per unit bit in multipath attenuation mode; $d$ is the distance of signal transmission; $d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$ is the critical value of dividing the spatial model.

## 3. Routing Algorithm Based on Non-uniform Clustering

In the ocean container IoT, in order to balance the energy costs of clusters with different distances from the convergence point, this paper mainly constructs clusters of non-uniform size through improved LEACH algorithm and competition radius. As the network scale is large, if the farther cluster head directly forwards data to the sink node, the energy cost of the cluster head will increase geometrically. In order to increase the network survival time, this paper designs a multi-hop transmission method between clusters. In the cluster head rotation, the cluster head rotation within the cluster is adopted. In order to ensure the rationality of the cluster head rotation, the optimal cluster head position is calculated and the cluster head rotation is performed based on the distance from the cluster center and the remaining energy of the node.

### 3.1 Cluster Establishment

At the beginning of the ocean transportation process, the service life of the container is different, and the service life of the corresponding sensor node is also different, so the energy reserve of each node is not uniform. In order to prolong the network survival time and ensure the connectivity of the network, in each round of cluster head selection, only nodes with sufficient remaining energy are eligible to participate in the cluster head election. Due to the existence of rechargeable reefer container nodes during transportation, the reefer node becoming the cluster head can balance the energy consumption of the network better than the general box node becoming the cluster head. The reefer node is preferred as the cluster head, which can avoid the general box node as the cluster head. And the energy consumption is too fast. Therefore, based on the traditional LEACH algorithm, the algorithm in this paper not only considers the remaining energy factor of the node, the average remaining energy factor of the network surviving nodes, and the neighbor node distribution density factor, but also considers the existence of the refrigerator node. When the node $s_i$ is a refrigerated container node, the weight $\mu = 1$, otherwise it is 2. Therefore, the $T(s_i)$ value generated by the reefer node is larger, and the probability of the reefer node becoming the cluster head is much greater than that of the general-purpose box node. The improved cluster head selection formula is as follows:

$$T(s_i) = \begin{cases} \dfrac{P_i}{1 - P_i\big(rmod(1/P_i)\big)} \left(\dfrac{E_{res}(s_i)}{\overline{E_{res}}}\right)^{\mu} \rho_{s_i}, & s_i \in G' \\ 0, & s_i \notin G' \end{cases} \tag{4}$$

Among them, $\rho_{s_i}$ represents the distribution density of neighbor nodes of node $s_i$; $E_{res}(s_i)$ and $\bar{E}_{res}$ represent the current remaining energy level of node $s_i$ and the average remaining energy level of all nodes in the current round of the network, respectively; $G'$ represents the set of nodes that are not selected as cluster heads after running $1/p$ round.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

In the process of cluster head election, it can be concluded from formula (7) that a certain node in the network is a refrigerated container node or its remaining energy and neighbor nodes in the zone have a higher distribution density. The larger the value of $T(s_i)$, the greater the The greater the chance of becoming a cluster leader.

If there is a refrigerated box cluster head node among the candidate cluster head nodes selected by $T(s_i)$, this type of node can directly become the optimal cluster head node without the need to calculate the competition radius to avoid unnecessary energy consumption. Although other candidate cluster head nodes fully consider the remaining energy of the node and the density of neighbor nodes, it is unavoidable that two nodes that are closer together become cluster heads at the same time. Therefore, this paper sets up the competitive radius formula of candidate cluster heads to select the optimal cluster head. The calculation formula for the competition radius of the general box node is as follows:

$$R_c = \left[1 - c\frac{d_{max} - d(s_i, BS)}{d_{max} - d_{min}}\right] R_0 \tag{5}$$

Since the cluster head close to the sink node not only receives the data in the cluster but also undertakes the data forwarding work, the energy consumption of this type of cluster head should be minimized, so the cluster head close to the sink node should have fewer member nodes, and the competition radius should be relatively small. Small, so that the cluster head can reserve part of the energy for communication between cluster heads. That is, as the distance between the candidate cluster head and the sink node increases, its competition radius also increases.

Remember that the maximum value of the competition radius of the candidate cluster head is $R_0$, and c takes a value between (0,1) to control the value range of the competition radius, so that the competition radius of the node closest to the sink node is $(1-c)R_0$. The candidate cluster head node calculates its own competition radius according to the above formula, and checks whether there are other cluster heads within its competition radius. If not, it becomes the optimal cluster head; if so, it checks whether it is a refrigerated container node. The refrigerated container node gives up becoming the cluster head.

After the cluster head election, the cluster head node broadcasts the message CluHead_MSG that it becomes the cluster head to the entire network. The ordinary node decides which cluster to join according to the received signal strength, and sends the join signal JOIN_CLU_MSG to the corresponding cluster head. After the container Internet of Things networking is completed, the cluster head allocates a time slot for sending information to each member node in the cluster. When sending messages, the member nodes in the cluster send their collected information to the cluster head according to their own message transmission time slot node.

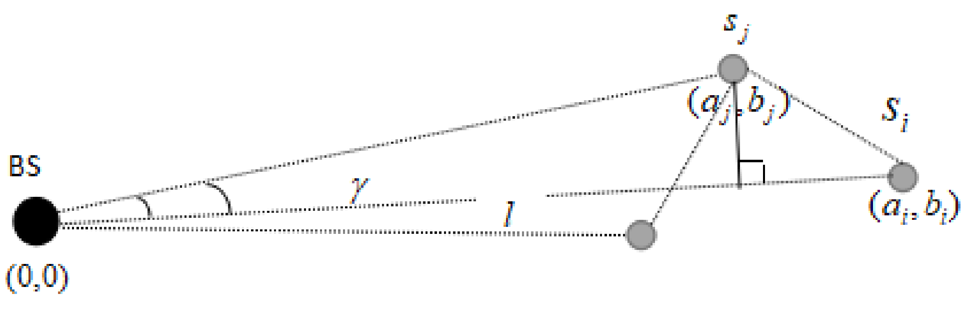


Figure 1. Distribution map of each node

### 3.2 The Inter-cluster Communication Phase

In the entire container Internet of Things, when the cluster head transmits data to the sink node in multi-hop communication, the cluster head close to the sink node is overloaded due to the large

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

amount of data being forwarded, and may run out of energy prematurely and fail. Cause the network to be paralyzed. Therefore, nodes that adopt multi-hop transmission need to select a suitable relay node for data forwarding. This paper considers the remaining energy of the relay node, the distance from the cluster head $s_i$ to the relay node $s_j$, and the distance from the relay node $s_j$ to the sink node. And the clustering radius of the relay node. Suppose the coordinate position of the sink node is (0, 0), the coordinate position of the cluster head node $s_i$ is $(a_i, b_i)$, and the coordinate position of the next hop relay node $s_j$ is $(a_j, b_j)$, as shown in the figure blow.

From the coordinate position in the above figure, $d(s_i, BS), d(s_i, s_j), d(s_j, BS)$ can be calculated. From the law of cosines:

$$cos\,\gamma = \frac{d(s_j, l)}{\sqrt{a_j^2 + b_j^2}} = \frac{d^2(s_i, BS) + d^2(s_j, BS) - d^2(s_i, s_j)}{2d(s_i, BS) \cdot d(s_j, BS)} = \frac{a_i a_j + b_i b_j}{\sqrt{a_i^2 + b_i^2} \cdot \sqrt{a_j^2 + b_j^2}} \tag{6}$$

Therefore, $d(s_j, l) = \frac{a_i a_j + b_i b_j}{\sqrt{a_i^2 + b_i^2}}$

The cluster head node calculates the weight $\omega$ by considering the above factors, and the weight calculation formula is as follows:

$$\omega = \alpha \cdot d(s_j, l) + \beta \frac{\bar{E}_{res}}{E_{res}(s_j)} + \gamma \frac{R(s_i)}{\bar{R}_{neighbor-s_j}} \tag{7}$$

Among them: $\alpha, \beta, \gamma$ are weighting coefficients, $\alpha + \beta + \gamma = 1$; $\overline{E_{res}}$ is the average value of the remaining energy of all cluster heads; $E_{res}(s_j)$ represents the remaining energy of the next hop node; $R(s_i)$ represents the clustering radius of node $s_i$; $\overline{R_{neighbor-s_j}}$ represents the average clustering radius of the neighbor cluster head nodes of node $s_j$.

Therefore, the shorter the distance between the relay node $s_j$ and the straight line l, that is, the shorter the data forwarding path of the cluster head node $s_i$, the more the remaining energy of the node $s_j$, the smaller the clustering radius, and the smaller the value of the weight $\omega$. Therefore, in order to select the optimal relay node, the node with the smallest weight ω should be selected as the next hop relay node. Therefore, the shorter the communication path between cluster heads, the smaller the energy consumption, the more beneficial it is to increase the survival time of cluster head nodes and banlance the energy consumption of the network.

### 3.3 Cluster Head Rotation Mechanism

In order to avoid the huge energy consumption caused by frequent rebuilding of clusters by the nodes of the whole network, this paper chooses the cluster head rotation mechanism in the cluster during the cluster head rotation process. Since there are refrigerated containers in the container Internet of Things, when selecting a new cluster head, it is necessary to first check whether there are refrigerated container nodes in the cluster. If it exists, judge whether it is eligible to be the cluster head according to $T(s_i)$. If $rand() < T(s_i)$, the refrigerated container node can directly become the new optimal cluster head; otherwise, the energy threshold $E_{th}$ and $d(s_j, s_i)$ are used to select the new cluster head.

If there is no refrigerated container in the container IoT, set the node energy threshold $E_{th}$. Once the energy of the cluster head node is less than this threshold, the cluster head will be discarded, and a new cluster head will be reselected in the cluster in order to make the new cluster head as close to the original as possible The condition of the optimal cluster head, so the remaining energy of the node and the distribution of the node in the cluster should be weighed.

First, the remaining energy of the nodes in the cluster is compared with the threshold one by one, and the nodes larger than the threshold are put into the set of candidate cluster head nodes.

$$E_{th} = 0.5 \times \overline{E_{res}} \tag{8}$$

ISSN: 2414-1895 | DOI: 10.6919/ICJE.202104_7(4).0029

Given that the coordinates of the center node of the cluster are $(a_i, b_i)$, set the coordinates of the candidate cluster heads as $(x_j, y_j)$, calculate the distance from each candidate cluster head in the set to the center of the cluster.

$$d(s_j, s_i) = \sqrt{\left(x_j - a_i\right)^2 + \left(y_j - b_i\right)^2} \tag{9}$$

According to the calculation results, the node with the shortest distance in the set is selected as the optimal cluster head node for the next round. This cycle is repeated until the energy of the nodes in the cluster is less than the threshold, and then the container Internet of Things networking process is restarted.

# 4. Experimental Results and Analysis

## 4.1 Parameter Settings

In order to fully verify the performance of this algorithm, the simulation experiment uses matlab to simulate the network survival time and energy balance. Based on the actual stacking of containers and the external dimensions of ordinary containers(2.35,2.35,12.08), matlab is used to generate a distribution of 100 nodes, evenly distributed in the three-dimensional spatial areas $(x = 0, y = 0, z = 0)$and$(x = 130, y = 15, z = 15)$. Once all nodes are arranged, their positions will not change. In this experiment, 10 nodes with infinite energy and 90 ordinary nodes with an initial energy of 0.5J are used. When the remaining energy is 0, the node is regarded as dead.The specific simulation parameters are set as shown in Table 1.

Table 1. Experimental parameters

| Parameters | Value |
| --- | --- |
| Network Coverage Area | (0,0,0,)~(130,15,15) |
| BS's Location | (135,7.5,7.5) |
| The Number of Sensor Nodes | 100 |
| The Initial Energy of Sensor Nodes | 0.5J |
| $E_{elec}$ | $50nJ/bit$ |
| $\varepsilon_{fs}$ | $10pJ/(bit \cdot m^2)$ |
| $\varepsilon_{amp}$ | $0.0013pJ/(bit \cdot m^4)$ |
| The Frequency of Data Communication | 1time/hour |
| Proportion of Charging Nodes | 0.1 |
| Cluster Head Ratio | 0.1 |

## 4.2 Analysis of simulation results

In the experiment, suppose $R_0 = 40m$, and the value of c is between (0,1), and observe how the time of the death of the first node in the network changes with c. The result is shown in the figure below. As c increases from 0 to 0.5, the death time of the first node in the network continues to be delayed, and when c is greater than 0.5, the death time of the first node gradually advances. Therefore, when c=0.5, the optimal competition radius is obtained so that the number of rounds of death of the first node is the longest. Therefore, the following experiments are all carried out when c=0.5.

It can be seen from Figure 3 that the improved LEACH algorithm can greatly increase the probability of the refrigerated container being elected as the cluster head by changing the cluster head election method, thereby reducing the energy consumption of other ordinary nodes, and the refrigerated container node shares most of the consumption. Energy, reducing the possibility of node death due to insufficient energy, so in the entire network life cycle, the number of node deaths in the improved LEACH algorithm is significantly less than that of the LEACH algorithm. The improved LEACH algorithm has the first dead node's turn significantly later than the LEACH algorithm. This is mainly due to the increased utilization of the entire container network node, which extends the effective life cycle of the network.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202104_7(4).0029

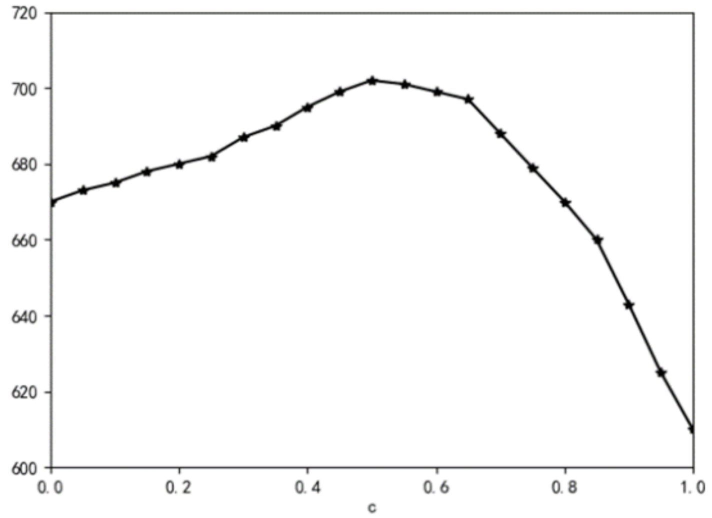


Figure 2. The trend of network survival time with c

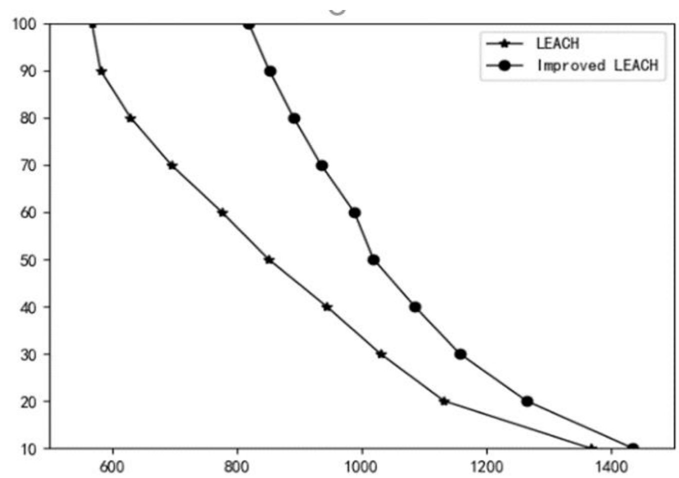


Figure 3. Comparison of network node survival trends

It can be seen from Figure 4 that, because the improved LEACH algorithm no longer conducts cluster head elections every round, it greatly reduces the energy consumption of the network, making the energy consumption of the improved LEACH algorithm less than that of the traditional LEACH algorithm during the entire network life cycle.

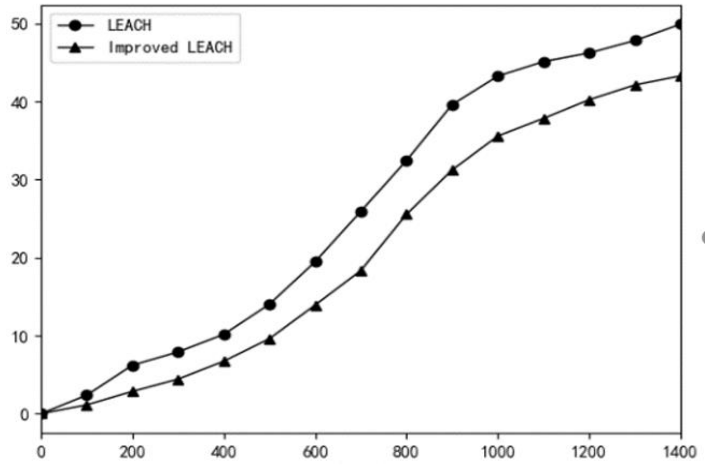


Figure 4. Comparison of network energy consumption trends

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029

In order to study the applicability of the improved LEACH algorithm proposed in this paper in large and medium-sized networks, the total number of nodes in the network is set to 300, 400 and 500 respectively under the condition that other experimental parameters remain unchanged. It can be seen from Figure 5 that through the comparison of the three algorithms under different network node numbers, it is obvious that the improved LEACH algorithm has a longer network life cycle than other traditional algorithms. As the total number of nodes increases, the improved LEACH algorithm The algorithm network life cycle is shortened by fewer rounds, which shows that the algorithm proposed in this paper has better applicability in large and medium-sized network environment.

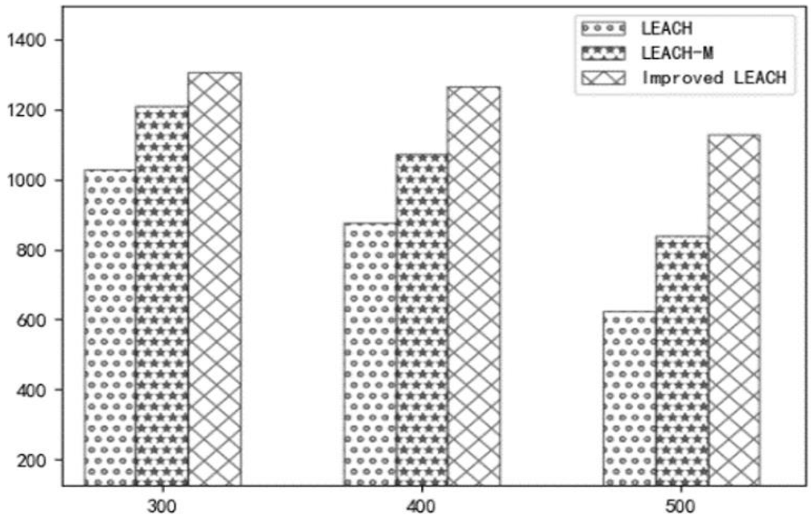


Figure 5. Comparison of the network life cycle and the total number of network nodes

## 5. Conclusion

In order to improve the current data transmission problems of the container IoT monitoring system in the ocean transportation process, this paper improves and optimizes the three stages of cluster establishment, inter-cluster routing and cluster head rotation. The experimental results show that with the increase of network operation rounds, the improved algorithm effectively balances the energy consumption of the network, better solves the "hot spot" problem, and realizes the efficient transmission and real-time monitoring of ocean shipping container information. In order to verify the practicability of the algorithm in this paper, experiments were carried out under three different network scale conditions. The results show that the improved algorithm is not only suitable for various scales of network environments, that is, suitable for various scales of container transportation Compared with other algorithms, it can extend the network life cycle and ensure the safety and quality of goods.

## References

[1] P.P. Pang,S. Liang, L.M. Xie. Improvement and simulation of LEACH protocol for multi-container monitoring [J].Journal of Sensing Technology,2009,22(12):1808-1812.

[2] L.H. Zhang. Design of Safety Monitoring System for Shipboard Dangerous Goods Container[D]. Dalian University of Technology, 2013.

[3] J.J. Shi. Research on security routing protocol of wireless sensor network monitoring system in container terminal[D]. Central South University,2010.

[4] J.W. Lai. Development of reefer container monitoring terminal based on low-orbit satellite communication and cellular mobile communication [D]. Shenzhen University, 2017.

[5] Lauf,J.O.and Gollmann,D.,2007, Monitoring and Security of Container Transports[C]. Proceedings of New Technologies, Mobility and Security 2007.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202104_7(4).0029


[6] Soro S, Heinzelman W. Prolonging the lifetime of wireless sensor networks via unequal clustering// Proceedings of the 5th International Workshop on Algorithms for Wireless, Mobile, Ad Hoc and Sensor Networks, Denver, CO, 2005.

[7] Heinzelman W R, Chandrakasan A, Balakrishnan H. Energy-efficient communication protocol for wireless sensor networks [C]// Hawaii International Conference on System Sciences. IEEE Computer Society, 2000: 8020.

[8] Mahapatra R P, Yadav R K. Descendant of LEACH based routing protocols in wireless sensor networks [J]. Procedia Computer Science, 2015, 57: 1005-1014.

[9] Y. Xu, L.G. Yuan, X.P. Zhu. A routing algorithm for sensor network combining node clustering and optimal distance[J]. Journal of Jilin University (Science Edition), 2016, 54(6):1373-1377.

[10] Y. Dong, Z.Z. Su, Z.Y. Zhou. An improved LEACH algorithm based on node residual energy and position[J].Journal of Sichuan University (Engineering Science Edition),2015,47(2):136-141.

[11] Y.X. Li, Y.X. Xu,L. He. WSN based on GA and LEACH introduces traffic layer path optimization algorithm[J]. Journal of University of Electronic Science and Technology of China, 2017,46(3):499-503.

[12] C.F. Li, G.H. Chen, M. Ye, J. Wu. A wireless sensor network routing protocol based on non-uniform clustering[J]. Chinese Journal of Computer,2007(01):27-36.

[13] L. Wang, W.W. Xie, Z.Z. Liu, J.Y. Qi. Improved algorithm of non-uniform clustering routing protocol [J]. Computer Science,2017,44(02):152-156.

[14] M. Li. Research on clustering routing algorithm based on multi-object in wireless sensor network [D]. Beijing University of Posts and Telecommunications,2018.

[15] Y.L. Pan, G.C. Liu. An energy-efficient clustering routing algorithm for wireless sensor networks [J/OL]. Application Research of Computers:1-5[2019-12-02].