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Joint Distribution and Route Optimization of 5G Networked Cold Chain Logistics for Fresh Agricultural Products

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Abstract: In the current fresh agricultural product consumption market, consumers' demand for fresh agricultural products tends to be diversified and personalized, and the cold chain logistics and distribution of fresh agricultural products are more stringent. This article mainly discusses the joint distribution and path optimization of 5G networked cold chain logistics of fresh agricultural products. Combining the advantages of 5G Internet of Things technology and the characteristics of fresh agricultural product, this paper proposes a fuzzy time window function, customer satisfaction function, loss function of fresh agricultural products, and establishes a path optimization model. First, analyze the cold chain distribution system of fresh agricultural products, find unreasonable aspects, and then put forward relevant suggestions to establish a path optimization model of agricultural products cold chain logistics distribution considering the cooling cost in the soft time window of the bicycle yard with non-full load. The amount, the load capacity of the vehicle, and the time window requirements are used as constraints. By using the CSO algorithm to solve the model, the cold chain distribution path of fresh agricultural products is optimized. The feasible optimization measures and schemes for the logistics distribution of agricultural products are obtained, and the distribution routes before and after optimization are compared, and the economic benefit level of the optimized route is obtained to a certain extent. It can be seen from the table that 75% of customers are very satisfied with this new type of freight transportation. It can be seen that the model has certain practical significance.

1. Introduction

Distribution and transportation have gradually become an important part of the cold chain logistics of fresh agricultural products, and urban distribution from the distribution center to each point of sale is the most easily overlooked link. With the development of society and the improvement of living standards, the agricultural industry structure has been continuously adjusted, the demand for fresh agricultural products has continued to increase, and the quality requirements have also improved. The processing, packaging, transportation, storage, sales and distribution of agricultural products have been become a topic of social concern. The concept of cold chain logistics is becoming more and more familiar to people[1]. With the development of the times, enterprises make the integration of online and offline to achieve common development through logistics[2]. In order to adapt to the new retail era, enterprises have carried out strategic layout and cooperation[3]. With the advent of the new retail era, consumers can shop through various channels, and consumers' shopping experience will become the top priority[4]. How to optimize the terminal logistics distribution method and deeply integrate online and offline, so as to improve the distribution efficiency and improve the shopping experience of consumers, is a research focus worthy of further study[5-6].

E-commerce of FAP has developed rapidly in recent years, but there are widespread phenomena such as high logistics costs and low profitability [7]. This paper takes the fresh electricity e-commerce logistics distribution model as the theme, and reduce the logistics transportation cost and improve the distribution efficiency, it has certain theoretical significance and practical significance [8]. The theoretical significance is to ensure the transportation efficiency[9]. Using mathematical modeling method, the path optimization problem is modeled and algorithm selected for the proposed common distribution mode, and the feasibility of the method is verified by a numerical example[10]. The current theoretical research is supplemented in the method [11]. The production of fresh agricultural products is not only to open up the sales methods of agricultural products, but also to reshape the supply chain of FAP and increase the convenience of supply[12]. The use of IoT technology is in line with the demand for food safety of fresh produce [13]. The practical significance can be divided into the following two points: the main goal of reducing the logistics cost of FAP e-commerce, which not only promotes the development of FAP e-commerce enterprises, but also guarantees the quality of agricultural products and stabilizes the prices of agricultural products[14]. And the development of modern agriculture can also make positive guidance [15]; carry out joint distribution, through the common distribution model for the logistics of FAP, not only reduce the logistics cost of fresh e-commerce, but also conducive to fresh e-commerce Enterprises rationally allocate resources to alleviate the pressure of urban transportation logistics [16]; the promotion and use of IoT technology, IoT technology can provide the detection of the quality and environment of FAP in the transportation process, and also realize the supply chain, the entire process of visual traceability reduces consumer concerns about food safety and enhances customer satisfaction [17].

Esfahani believes that in the emerging Industrial Internet of Things (IIoT) era, machine-to-machine (M2M) communication technology is considered as a key underlying technology for building an IIoT environment [18]. Yaqoob I argues that the explosion of smart objects and their reliance on wireless communication technologies increases the vulnerability of the Internet of Things (IoT) to cyberattacks. The cyberattacks facing the Internet of Things present a daunting challenge for digital forensics experts. Various forensic techniques are employed to investigate such attacks. These techniques are designed to track both internal and external attacks by highlighting the communication mechanisms and architectural vulnerabilities of IoT. In his research, he explores new factors in which the Internet of Things affects traditional computer forensics. He investigates recent research on IoT forensics by analyzing their strengths and weaknesses. He classifies and categorizes literature by designing taxonomies based on forensic stages, enabling factors, networks, sources of evidence, investigation patterns, forensic models, forensic layers, forensic tools, and forensic data processing. He also lists some prominent use cases for IoT forensics and describes the key requirements to enable IoT forensics. Finally, he identified and discussed several indispensable open research challenges as future research directions [19]. Ye Q built an analytical end-to-end (E2E) packet delay model for multiple traffic flows traversing embedded virtual network function (VNF) chains in fifth-generation communication networks. Generalized processing sharing of dominant resources is adopted to allocate computing and transmission resources among the flows of each Network Function Virtualization (NFV) node to achieve fair distribution of dominant resources and high resource utilization. A concatenated queuing model is developed to characterize packets of multiple flows through NFV nodes and their outgoing transport links. For ease of analysis, he decoupled the packet processing (and transmission) of the different flows in his modeling, and determined the average packet processing and transmission rate for each flow as an approximate service rate. He developed an M/D/1 queuing model to calculate the packet delay per flow on the first NFV node. Based on the analysis of the packet arrival times of subsequent NFV nodes, we adopt the M/D/1 queuing model as an approximation to estimate the average packet delay per flow for each subsequent NFV node. The queuing model was shown to achieve more accurate latency estimates than using the G/D/1 queuing model. The packet transmission delay on each embedded virtual link between consecutive NFV nodes is also derived for E2E delay calculation [20].

This paper combines the characteristics of 5G IoT technology with the logistics, establishes a logistics distribution path optimization model. In order to verify the model, the improved genetic algorithm was selected, simulated. The experimental results show that the model has a realistic effect on the optimal route selection of FAP .The time window and consumer satisfaction problems affecting the distribution path optimization were discussed. On this basis, the optimization objective of fresh agricultural products distribution was obtained, and the distribution path optimization model was established. Finally, a numerical example is given to verify the model with genetic algorithm and Matlab software.

2. Proposed Method

2.1. 5G IoT

The 5G IoT integrates two-dimensional code reading devices, radio frequency identification technology, infrared sensors, GPS and other sensors. According to the corresponding agreement, the Internet is connected with the goods to realize information exchange and recognition. A network of positioning, tracing, monitoring and management.Establish an efficient and reasonable 5G IoT fresh agricultural product cold chain logistics system, thereby reducing circulation links, improving the circulation environment, and improving the circulation efficiency of fresh agricultural products. Common IoT devices in life are shown in Figure 1.

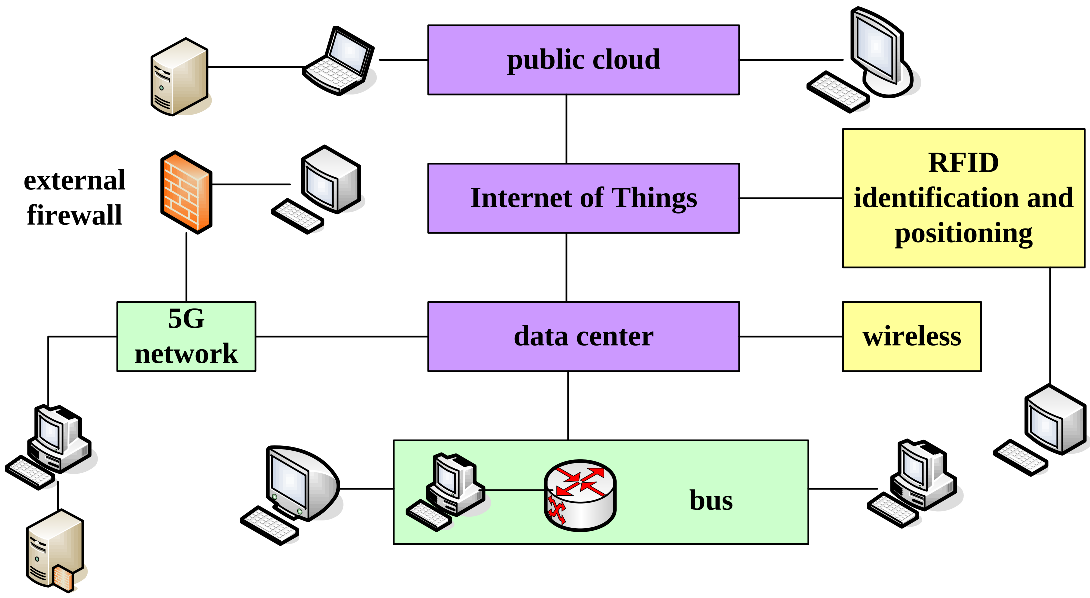

Figure 1. Common IoT devices

2.2. Analysis of Logistics Distribution Mode of FAP under the 5G IoT Environment

The paper analyzes the shortcomings of using the original method in the fresh produce delivery. Based on the advantages of the current5G Internet of Things technology and the particularity of fresh agricultural products, we innovatively combine the 5G Internet of Things technology with distribution to form a new mode of agricultural product distribution that is both practical and professional. Fresh agricultural products are different from other goods, and their particularity also requires that they must have their own characteristics during distribution. Specifically, it is to innovate in the production and processing links, as well as warehousing and distribution, and at the same time realize the intelligent operation of sales, traceability and the above-mentioned links. Improve the utilization rate of agricultural products and the level of informatization to the greatest extent. Gradually shift the mode of operation of agriculture to an intensive one.The logistics distribution mode of FAP in the 5G IoT environment is shown in Figure 2:

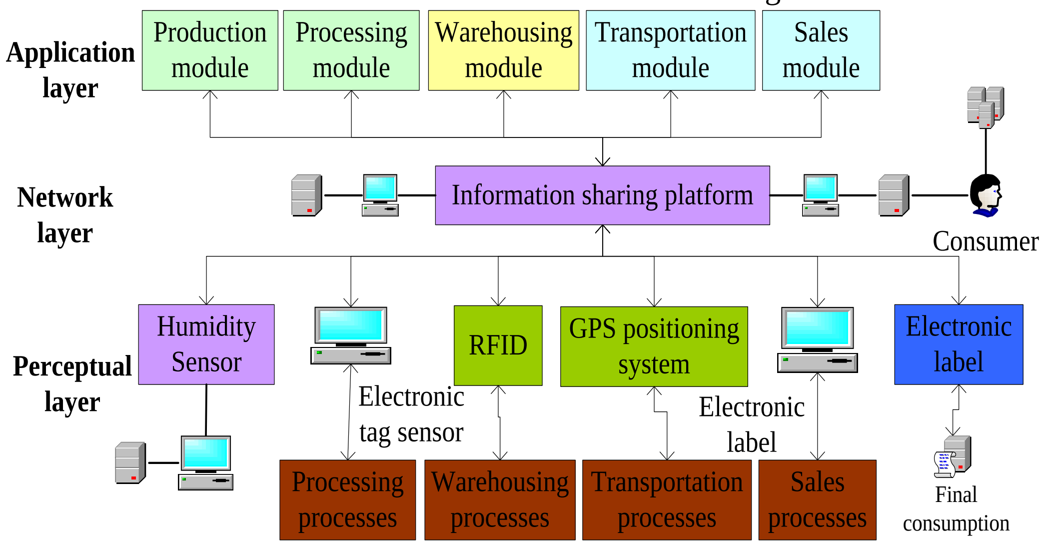

Figure 2. Logistics distribution model of FAP under 5G IoT environment

2.3. Optimization Model of Fresh Agricultural Products Distribution Route in 5G Internet of Things Environment

(1) Production link

The production of agricultural products needs to go through multiple stages, and each stage requires different requirements for temperature and humidity. Therefore, in this stage, technologies such as GPS positioning and infrared remote sensing are applied to the acquisition of agricultural product information. Real-time collection and processing of information brings great convenience to growers and managers of agricultural products, and can take effective countermeasures based on the processed information.

The location and cargo demand $g_i = (1,2,...,N)$ of the customer i has been determined. Therefore, this paper blurs the time window to meet the actual time requirement of customer i, and defines customer satisfaction time $U(s_i)$ as the membership function of service start time:

$$U(s_i) = \begin{cases} (\frac{S_i - eeT_i}{eT_i - eeT_i})^\beta & S_i \in [eeT_i, eT_i] \\ 100\% \quad S_i \in [eet_i, lT_i] \\ (\frac{eeT_i - S_i}{elT_i - lT_i})^\beta & S_i \in [lT_i, elT_i] \\ 0 \quad S_i \notin [eeT_i, elT_i] \end{cases} \tag{1}$$

Where S_i is the start time of the customer service, and the fuzzy time window of the customer i is divided into two parts, the expected service time period and the tolerable service time period, namely $[eT_i, lT_i],[eeT_i, elT_i]$.

(2) Processing link

The agricultural product processing link based on 5G IoT technology is also different from the traditional processing mode. For example, the RFID technology encodes the information of the harvested agricultural products, and each encoded information corresponds to a fixed electronic tag. Managers or consumers can use mobile phones and other terminals to scan the codes to obtain information on agricultural products. For example, how the agricultural products are processed, the specific information in the processing link, etc.

(3) Warehousing link

When the agricultural products are put into storage, the RFID technology is used to read the electronic label identity established by the agricultural products in the production process, and the system will automatically send the agricultural products to the set distribution route and the location of the goods. Every piece of agricultural product will have detailed location tracking, and finally the data information of the storage location of the agricultural product will also be saved.

The satisfaction $U(S_i) \geq \theta$ of each customer i is guaranteed.

$$f(i,\theta) = (\frac{s_i - eeT_i}{eT_i - eeT_i})^\beta, G(i,\theta) = (\frac{eeT_i - S_i}{elT_i - lT_i})^\beta \tag{2}$$

When meeting customer i's minimum satisfaction, the service start time range is $[I(i,\theta), S(i,\theta)]$:

$$S(i,\theta) = g_i^{-1}(i,\theta) = \theta^{1/\beta} \cdot lT_i + (1-\theta^{1/\beta}) \cdot elT_i \tag{3}$$

$$I(i,\theta)=f_i^{-1}(i,\theta)=\theta^{1/\beta}\cdot eT_i+(1-\theta^{1/\beta})\cdot eeT_i \tag{4}$$

(4) Delivery link

Using GIS and E_map to provide the basic information of vehicle transportation, the Internet of Things technology can combine and analyze the vehicle information and road information, and set the optimal route for the loading of agricultural products and the transportation location to be delivered, reduce transportation costs.

2.4. Fresh Produce Distribution Costs

(1) Vehicle transportation cost

The transportation cost of the vehicle consists of two parts, one is the fixed cost of deploying the vehicle, and the other is the variable cost of the vehicle. The fixed cost mainly includes the corresponding expenses for the vehicle when the vehicle is assigned for the delivery service.

This fee basically does not change with the distance traveled by the delivery vehicle, and is not directly related to the number of customers served. The specific fee includes the cost of the driver, vehicle wear and tear, depreciation and other expenses. In order to facilitate the final calculation, this paper only studies the one delivery driver costs and vehicle wear and tear in the process.

The vehicle transportation cost formula is:

$$F_1=F_0K+\sum_{K=1}\sum_{i=1}\sum_{j=1}cx_id_j \tag{5}$$

(2) Penalty cost for violating the time window

Because agricultural products are time-sensitive, customers have requirements for the delivery time of agricultural products. Most of the customers have a cooperative relationship with the company and are long-term and stable customers. Therefore, customers can usually accept a slightly earlier or delayed delivery time, but they need to pay the corresponding penalty cost, which will also affect customer satisfaction. Therefore, the soft time window constraint is adopted in the model.In the actual delivery process, due to the unreasonable route planning of the distribution center or the road congestion of the delivery vehicle during the delivery, the delivery service cannot be completed within the required time window, and the customer will refuse to receive the goods, which will have an impact on the company's reputation, this situation must be resolutely avoided.

(3) Refrigeration costs in the process of vehicle distribution of fresh agricultural products

Agricultural products are perishable. In order to ensure the quality of agricultural products, the distribution method of cold chain logistics is required.

1) Refrigeration costs incurred during vehicle distribution

The cooling cost incurred during the transportation of the vehicle can be obtained from the following formula:

$$Q=(1+\partial)\times F\times\Im\times(T_2-T_1) \tag{6}$$

Q stands for body heat load of the passenger compartment and $\Im$ stands for thermal conductivity.

The cooling cost of vehicle k during the delivery process can be expressed as:

$$C_{TK}=Q_S\times\lambda\times T\times F \tag{7}$$

2) Refrigeration costs incurred when serving customers

When arriving at the customer and unloading the product from the compartment, the door of the delivery vehicle is opened, and the cold air in the compartment is convected with the warm air outside, and the heat exchange inside and outside the car is completed through the compartment door.

3. Experiments

3.1. Data Collection

The distribution center has a total of 5 vehicles, each with a load of 9 tons, and the fixed cost of each vehicle is 11 yuan; the average freight speed is 40km/h, and the required unloading speed is 6kg/m; the waiting fee is 15 yuan, and the delay fee is 50 yuan. The details are shown in Table 1.

Table 1. Delivery vehicle information table

serial number	Nuclear load	cost	speed
1	9	15	40
2	9	15	40
3	9	15	40
4	9	15	40
5	9	15	40

3.2. Experimental Environment

The experiment in this paper is carried out on a desktop computer equipped with WINDOWS7 system. The experimental software is MATLAB and the software version is 2015b.

3.3. Algorithm Steps

During the experiment, the number of iterations of the population was 200, and the population size was 10. The simulation was performed under the MATLAB R2014a program. In this environment, the chaotic cat swarm algorithm (CCSO), the basic cat swarm algorithm (CSO) and the genetic algorithm (GA) 20 times each, and the optimal result obtained is the optimal fitness value.There are seven basic elements in the genetic algorithm, which have their own unique functions: one is coding. The solution space must be converted into the corresponding data codes through a certain algorithm, and then the tracking operation is carried out according to these data codes; the second is the setting of the initial group. Randomly generate some initial populations, and then carry out the relevant algorithms and estimate the results; the third is the determination of the fitness function: the fourth is the selection; the fifth is the crossover; the sixth is the mutation; the seventh is the operating parameters.

Step1:Assuming that there are n customers (n=1, 2, 3, .., n) that need to be delivered, n customers are regarded as n nodes, and it is assumed that 1 is selected as the base point.

Step2:Connect n-1 nodes to 1 to form n-1 lines.\

Step3:Connect point i and point j (i≠j≠1), and calculate the saving value according to the formula:

$$s(i,j)=F_{1i}+F_{1j}-F_{ij} \tag{8}$$

Step4:Calculate the saving value of all nodes after connecting two by two, find the largest s(i,j) among all saving values, and insert its node into the delivery route.

Step5:Repeat the above steps until all nodes are included in the distribution route.

4. Discussion

4.1. Optimal Route Result Analysis

(1) Analysis of distribution of distribution centers and customer points

According to the specific case data, the geographical distribution map of the distribution center and the customer point is drawn. Points [60, 140] are the distribution center coordinate points, and the remaining points represent the customer coordinate points. There are 11 customers in total.The distribution of the distribution center and customer points is shown in Figure 3:

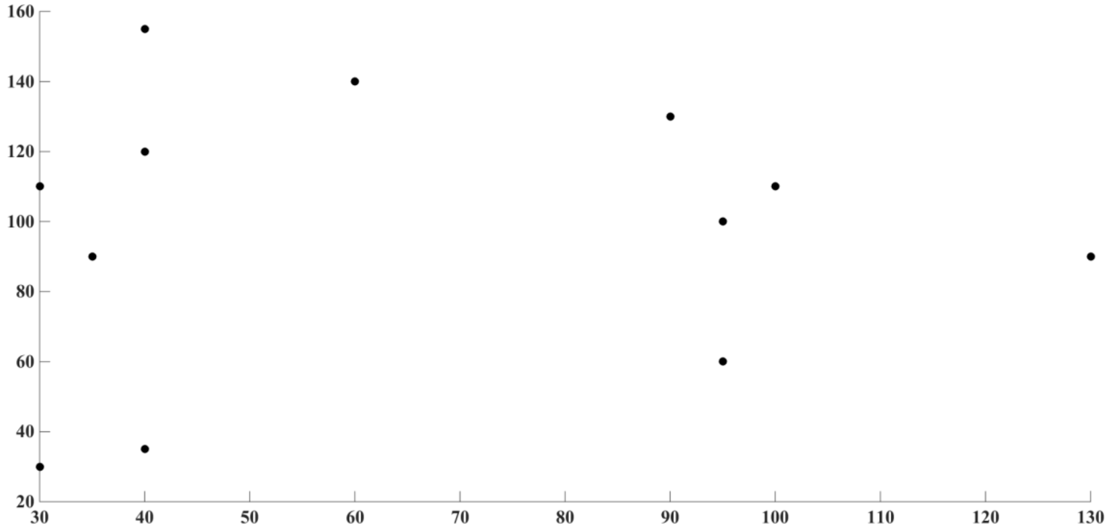

Figure 3. Location map of distribution center and customer points

(2) Analysis of population evolution trend after running a single genetic algorithm

The convergence judgment of genetic algorithm is different from the traditional mathematical programming method. It is a heuristic search without strict mathematical convergence. In this paper, the improved genetic algorithm is used to simulate the model. It not only saves the number of refrigerated trucks used, but also greatly shortens the distribution distance and saves costs.The evolution trend of the population after the single genetic algorithm is shown in Figure 4:

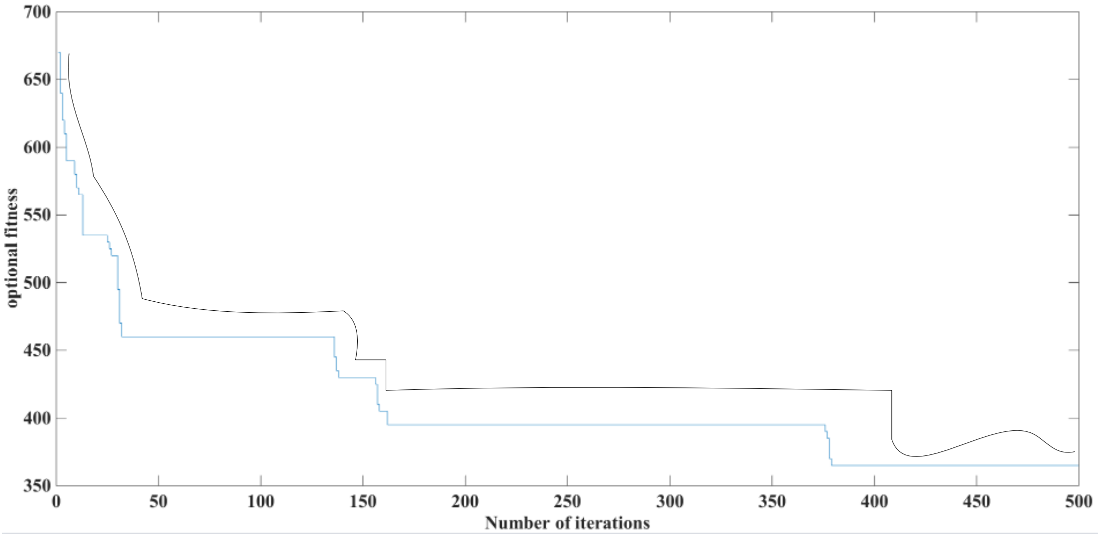

Figure 4. Population evolution trend after running a single genetic algorithm and improved algorithm

(3) Analysis of the results of multiple genetic algorithms

In order to obtain a better solution, this paper uses several genetic algorithm superposition solutions to obtain two sets of approximate optimal solutions, one of which is the best transportation route. The transportation route is shown in Figure 5:

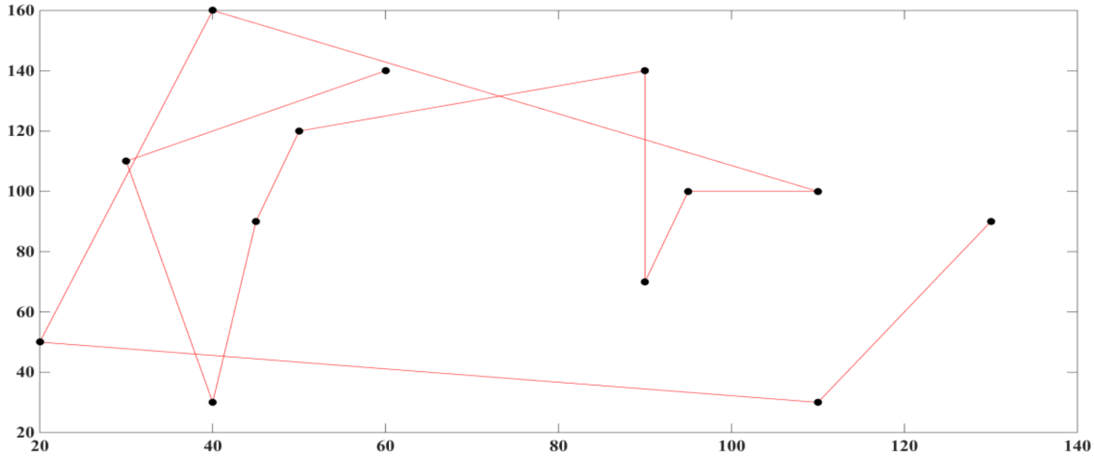

Figure 5. Schematic diagram of the best transportation route

(4) Analysis of the best transportation route

The above-mentioned single genetic algorithm solution results and two sets of multiple genetic algorithms are compared and analyzed to obtain approximate optimal solutions, as shown in Table 2 and Figure 6:

Table 2. Comparison of solution results

Solution method	Distribution cost	Customer satisfaction	Spend time	Distance
Single Genetic Algorithm	610.8666	0.66968	13.6312	996
Multiple genetic algorithms: scenario 2	366.6698	0.86261	9.3689	868
Multiple genetic algorithms: scenario 3	360.6688	0.68263	12.8662	866

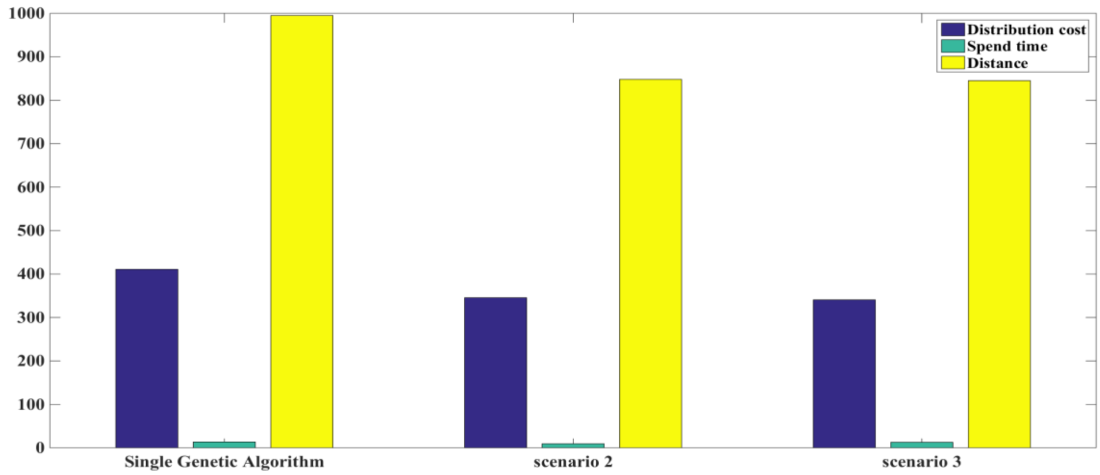

Figure 6. Comparison of solution results

In Figure 5, 1, 2, and 3 of the abscissa represent a single genetic algorithm solution result, a plurality of genetic algorithm scheme 1 and a plurality of genetic algorithm scheme 2, respectively. It can be seen from the results that the results obtained by superimposing multiple genetic algorithms are superior to the single genetic algorithm. Scheme 1 and Scheme 2 are two approximate optimal solutions after the superposition of multiple genetic algorithms. The distribution cost of Scheme 1 is slightly higher than that of Scheme 2, but considering the cost of agricultural products, customer satisfaction and time spent are better than Scheme 2.

4.2. Customer Satisfaction Results

In order to explore the degree of customer satisfaction with the delivered goods, this article conducted a satisfaction survey on 20 customers. The basic information of the customers is shown in Tables 3, 4 and 5.

Table 3. Gender distribution of customers

gender	male	Female
Number of people	16	4
Proportion	80%	20%

Table 4. Customer age distribution table

age	Under 30	30~40	40~50	50~60	Over 60
Number of people	6	4	5	3	2
Proportion	30%	20%	25%	15%	10%

Table 5. Customer income distribution table

age	Under 1w	1w~2w	2w~3w	3w~4w	Over 4w
Number of people	1	4	7	6	2
Proportion	30%	20%	25%	15%	10%

The collected customer satisfaction survey data is shown in Table 6.

Table 6. Customer satisfaction table

satisfaction level	Very satisfied	Generally satisfied	Not so satisfied
Number of people	15	4	1
Proportion	75%	20%	5%

It can be seen from the table that 75% of customers are very satisfied with this new type of freight transportation. The transportation route of this transportation method based on the Internet of Things is very optimized and the transportation efficiency is also very high.

5. Conclusion

Compared with other logistics, cold chain logistics has certain particularity. The realization of refrigeration and freezing technology makes the cost borne by enterprises relatively high, which makes cold chain logistics face huge challenges.By studying the current situation of cold chain logistics, this paper completes the construction of the distribution path optimization model of cold chain logistics in the 5G Internet of Things environment, and through the design of genetic algorithm, the implementation of MATLAB software to program and solve, to prove its feasibility.From the perspective of building a 5G IoT distribution system, this paper discusses the logistics and distribution of agricultural products, especially the problems existing in the old system under the influence of the traditional e-commerce information platform. Five aspects: first, the main supply of agricultural products; second, distribution of logistics distribution sites; third, utilization and overall planning of distribution enterprise resources; fourth, optimization and upgrading of logistics network structure; fifth, logistics distribution system overall analysis of the operation process.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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