

Research on drone logistics layout based on different scenarios

Yuyang Liao^{1,*}, Feiyang Liao²

¹College of Computer Science and Cyber Security (Pilot Software College), Chengdu University of Technology, Yibin, China, 610051

²School of Material Science & Chemical Engineering, Hubei University of Technology, Hubei, China, 430072

* Corresponding Author Email: m13696022516@163.com

Abstract. Domestic and foreign drone logistics giants have developed different delivery solutions based on different delivery needs of customers and derived different application scenarios. Among them, the Zhihang logistics industry solution combines "App+Data Center" applications to provide users with the function of real-time monitoring of the flight status, flight trajectory, and logistics package information of each drone in the logistics system. This solution provides a safer and more efficient solution for the logistics industry. At the same time, the point-to-point solution launched by Xunyi activates preset routes, autonomously completing flight missions from the origin point to the destination, and returning to standby mode after unloading at the destination, waiting for the next mission. This solution has the characteristics of efficiency and convenience, bringing new breakthroughs to the express delivery industry.

Keywords: Drone Logistics, Zipline Platform, Intelligent Warehousing, 5G Network

1. Introduction

Zipline, a foreign courier service company dedicated to using drones to provide medical supplies, utilizes data and advanced analytical tools for predictive analysis, predicting factors such as demand, traffic conditions, and weather in advance, in order to more effectively plan and schedule drone flight missions. Due to Zipline's drone system focusing on providing emergency medical supplies, the company has a rapid response team that can immediately activate and deploy drones upon receiving emergency requests to quickly respond to emergencies or medical needs. In addition, Zipline's system supports real-time interactive communication with partners. Medical institutions can submit orders through the Zipline platform and communicate directly with the operations center to ensure timely material delivery. By combining these technologies and strategies, Zipline can maximize the efficiency and reliability of its system, ensuring timely and accurate delivery of medical supplies to the required locations in emergency situations. The application of this technology provides an innovative solution for remote areas and emergency medical assistance.

In 2013, Amazon first announced its drone logistics plan - "Prime Air". This innovation has completely changed the traditional mode of the logistics industry from warehousing to transportation, and then to delivery, showcasing the beautiful vision of a comprehensive and three-dimensional intelligent logistics system^[1]. Amazon's move not only heralds a revolution in the future of the logistics industry, but also opens the door to the development of global drone logistics^[2]. The drone delivery business under the Google Brothers company Wing has officially launched in the United States, pioneering the commercial era of drone transportation in the United States. The Federal Aviation Administration (FAA) is also strongly supporting and promoting the development of its unmanned aerial vehicle logistics technology^[3]. In the domestic drone logistics development industry, on the one hand, e-commerce companies such as JD.com and Suning have begun to explore new models of drone logistics distribution. They aim to build a three-level unmanned aerial vehicle logistics distribution and navigation logistics system for trunk, branch, and terminal lines, gradually building an intelligent logistics network that integrates heaven and earth, aiming to provide users with more convenient and fast logistics services^{[4][5]}. On the other hand, logistics companies such as SF

Express and China Post, as well as professional drone service providers such as Zhihang, Yihang, and Xunyi, are actively innovating in their respective fields and continuously launching new drone logistics solutions.

2. Research on General Scheme of Drone Logistics System

2.1. In depth analysis of requirements and customized strategies

Through market research and data analysis, this article will gain a deeper understanding of the current situation, development trends, and real needs of users in the logistics market. This not only includes the explicit needs of customers, but also includes those potential needs that have not been fully explored. On this basis, targeted drone logistics solutions will be developed to ensure that each solution can accurately hit the pain points of the market^[6].

For different industries and regions, this article will provide personalized logistics services based on their specific demand characteristics, such as goods type, transportation frequency, transportation distance, etc. From this, it can be seen that only deeply customized services can ensure the maximum value of drone logistics in various complex scenarios.

2.2. Intelligent warehousing and efficient inventory management

This article will introduce intelligent warehousing systems and utilize automation technologies such as AI and the Internet of Things to achieve efficient and automated warehouse operations, thereby improving overall efficiency. This includes but is not limited to automated functions such as loading, unloading, and inventory of goods.

At the same time, by implementing intelligent inventory management, we can real-time grasp the quantity, status, and other information of each type of goods, and optimize the warehouse layout according to actual needs, ensuring efficient storage and pickup of materials. This will greatly reduce cost waste caused by poor inventory management.

2.3. Refined scheduling and intelligent path planning

An efficient scheduling system will be the core of the unmanned aerial vehicle logistics system. This article will establish such a system to achieve real-time monitoring and scheduling of drone flight tasks, ensuring that each flight is executed in the optimal state^[7].

In terms of path planning, this article will adopt advanced algorithms and comprehensively consider various factors such as meteorological conditions, traffic conditions, flight altitude, etc. to plan the optimal flight path for unmanned aerial vehicles^{[8][9]}. This not only concerns efficiency, but also directly affects the safety and economy of flight.

To meet different logistics needs, we will adopt a variety of drone models and technologies. We have corresponding drone technology to support both small package express delivery services and emergency transportation of large goods^[10].

In order to achieve efficient operation of the overall logistics system, we will also introduce unmanned vehicles, ground robots and other equipment to form a collaborative working mode with drones. Through this model, various devices can cooperate with each other to achieve seamless logistics services from the warehouse to customers throughout the entire process.

2.4. Data driven optimization and flight safety assurance

By using big data analysis techniques, we will conduct in-depth mining and analysis of the data generated during logistics transportation, in order to identify potential problems and improve space, thereby continuously improving transportation efficiency and service quality.

Flight safety has always been our top priority. Therefore, we will establish a real-time monitoring system to track the real-time position, status, and obtain relevant environmental data of the drone^[11].

Through this data, we can promptly identify potential safety hazards and take corresponding measures to ensure flight safety.

3. Research on Low Altitude Takeout Delivery in Drone Cities

With the increasing maturity and popularity of drone technology, urban low altitude takeout delivery, as a new type of delivery method, is gradually changing the traditional logistics model. As the core link of the entire distribution system, drone cluster scheduling is crucial for ensuring the timeliness, safety, and efficiency of distribution. This case study will delve into the strategies and technical implementation of drone cluster scheduling in urban low altitude takeaway delivery, as well as the challenges it faces.

5G technology, as a fifth generation mobile communication technology, has the characteristics of high bandwidth, low latency, high connectivity, and high reliability. In the field of drones, 5G technology provides real-time and efficient data transmission capabilities for drones. Drones can transmit high-definition videos, flight control signals, and other large amounts of data in real-time through 5G networks, achieving the integration of data transmission and image transmission. This not only improves the efficiency of drones, but also makes remote control more precise and timely^[12]. At the same time, satellite Internet technology also provides a global Internet connection for UAVs. By using satellites as relay stations to transmit microwave signals, drones can communicate between different ground stations and achieve global data transmission. This technology has the advantages of low latency, low cost, wide coverage, and broadband, providing a more stable and secure communication environment for drones. In terms of data link technology, 5G connected drones have improved the stability and security of data transmission by optimizing the design of data links. The data link between the drone platform system and the ground command and control system adopts efficient data encoding and transmission protocols, ensuring the integrity and accuracy of data. At the same time, the drone is also equipped with advanced security protection mechanisms, such as data encryption and identity verification, to prevent data leakage and illegal access.

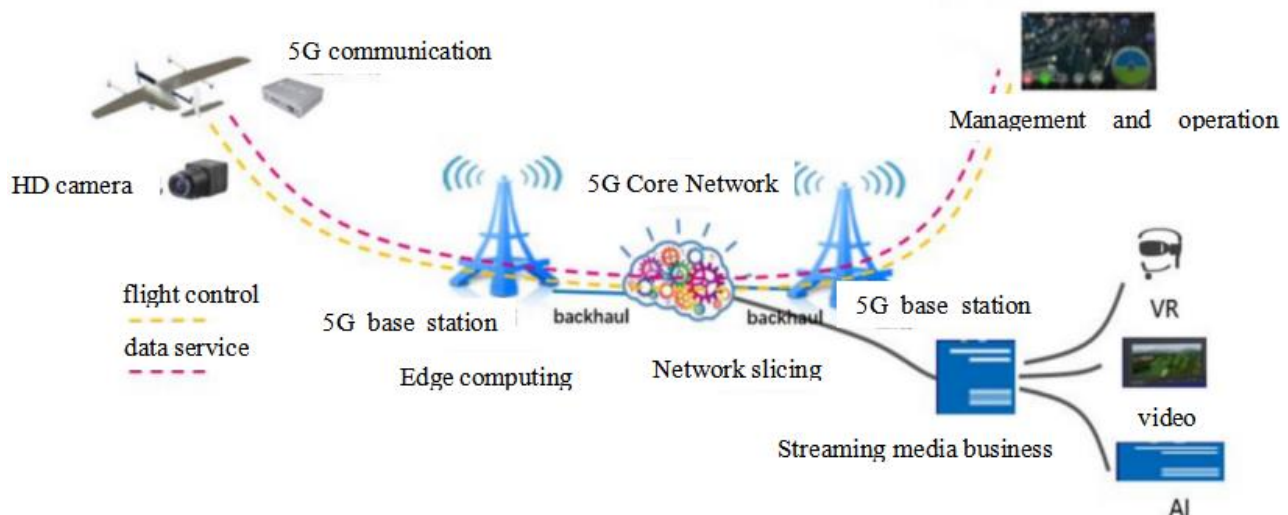


Figure 1. Flow chart

As shown in Figure 1, In the exploration of drone cluster scheduling strategies, this article delves into multiple key links and conducts corresponding optimization and innovation. Firstly, intelligent path planning is the foundation of drone cluster scheduling. Advanced multi-objective optimization algorithms such as NSGA-II are utilized to consider factors such as flight distance, time, and obstacles, in order to design the optimal flight path for the drone cluster. At the same time, considering the complexity and real-time variability of the urban environment, we combine real-time traffic data and weather information to dynamically adjust the flight path, ensuring that drones can efficiently and safely complete delivery tasks in complex and ever-changing urban environments.

Secondly, collaborative flight control is the key to achieving intelligent drone swarms. We have achieved autonomous decision-making and execution capabilities of drone clusters through inter machine collaborative communication and simple control between cluster machines. The application of microwave data links ensures real-time communication and data transmission between drones, making cluster flight more collaborative and consistent.

In terms of task allocation and priority adjustment, precise task allocation and priority adjustment are carried out for the drone cluster based on factors such as the geographical location, delivery time, and urgency of delivery orders. With the help of multi-objective genetic algorithms such as MOGA, the optimal solution for multi-objective path planning and task allocation can be found, ensuring that the drone cluster completes as many delivery tasks as possible in a limited time.

In addition, technological implementation is also an indispensable part of drone cluster scheduling. This article adopts a one-stop multi machine control mode, utilizing advanced measurement and control systems and communication technology to achieve monitoring and control of telemetry and video information from multiple machines. The construction of a drone cluster network enables real-time transmission and sharing of information, improving the real-time and accuracy of the scheduling system.

In terms of data analysis and prediction, big data analysis techniques are used to deeply mine and analyze historical distribution data, and predict future distribution demand and trends. Based on these prediction results, this article can advance the scheduling and resource allocation of drone clusters, thereby further optimizing the distribution process, improving distribution efficiency and service quality.

It is worth noting that the path planning problem of unmanned aerial vehicles has always been a hot and difficult research topic. The traditional offline optimization methods based on known ground base station positions and communication channel knowledge are no longer able to meet the needs of modern urban distribution. Therefore, some scholars have proposed methods for constructing channel gain maps and signal-to-noise ratio maps, and have used the shortest path problem solving method in graph theory to achieve more accurate and efficient path planning. This method not only considers the dynamic changes of channels and interference in space, but also can plan the optimal flight path for unmanned aerial vehicles while ensuring communication quality.

The research on unmanned aerial vehicle (UAV) single machine multi package transportation at home and abroad is not deep enough. When carrying multiple packages and optimizing multi task paths, how to coordinate is a problem. How to find a path that can reach all task points and return to the starting point under high-density buildings and obstacles is a TSP problem. However, there is currently relatively little research on the TSP path planning problem under obstacle constraints. The main method to solve such problems in the past was to set the distance between cities that cannot be directly reached to infinity. However, when there are multiple obstacles, this method converges slowly and may even have no solution.

4. Research on Material Distribution in Dangerous and Remote Areas

Firstly, considering the endurance of drones, high-performance lithium or fuel cells will be used to significantly improve their energy density and service life.

At the same time, in order to shorten the charging time, fast charging technology will be studied and applied to ensure that the drone can quickly return to full charge within a short charging cycle, thereby improving the overall delivery efficiency.

Low energy consumption brings high endurance, and efforts can also be made in lightweight design of drones to reduce energy consumption. Lightweight materials such as carbon fiber and aluminum alloy can be used to reduce the weight of drones. At the same time, by optimizing structural design, unnecessary weight can be reduced, energy consumption can be reduced, and the endurance time of drones can be further extended. Low energy consumption brings high endurance, and efforts can also be made in the lightweight design of drones to reduce energy consumption. Lightweight

materials such as carbon fiber and aluminum alloy can be used to reduce the weight of drones. At the same time, by optimizing structural design, unnecessary weight is reduced, energy consumption is reduced, and the endurance of the drone is further extended.

When facing the challenge of insufficient battery life, vehicle aircraft collaboration or multi aircraft collaboration strategies are also very effective solutions. Vehicle machine collaboration has evolved from one vehicle, one machine to one vehicle, multiple machines, and then to multiple machines and vehicles. These strategies not only improve the efficiency and scope of distribution, but also increase the flexibility and reliability of the entire logistics system.

Firstly, the collaborative mode of one vehicle, one machine has its unique advantages in the initial stage. This mode combines the long-distance transportation capability of vehicles and the air delivery capability of drones, enabling fast and accurate delivery in specific areas. However, when the endurance of drones becomes a limiting factor, this mode may not be able to meet large-scale or long-term delivery needs.

In order to overcome this limitation, the collaborative mode of one vehicle with multiple machines has emerged. In this mode, a vehicle can carry multiple drones, which can be rotated for delivery, thereby extending the overall delivery time and scope. The advantage of this model is that it can significantly improve delivery efficiency and coverage area without increasing the number of vehicles. Meanwhile, through reasonable scheduling and planning, collaborative work between drones can be ensured, avoiding resource waste and conflicts.

A study has proposed an optimization and planning framework for joint ground and air parcel delivery services, aimed at minimizing total delivery costs, taking into account the uncertainty and fault conditions of drone parcel delivery. By using a three-stage stochastic integer programming model and decomposition method, this framework demonstrated significantly lower total payment costs in experiments.

Another study considered the scenario of unmanned aerial vehicles (UAVs) traveling at different speeds in a last mile delivery system, which includes a truck and a drone fleet. By dynamically adjusting the speed of drones to achieve excellent performance, this article provides a three-stage algorithm aimed at minimizing the total delivery time (or completion time). The results indicate that significant time savings can be achieved by operating drones at variable speeds, and under certain conditions, optimizing drone speeds can also reduce truck travel distance, drone energy consumption per trip, and drone hovering while waiting to meet trucks.

Given the limitations of previous methods, there are also studies aimed at studying the trajectory planning problem of cargo drones with disconnection perception and switching perception. Specifically, this study aims to minimize the energy consumption and switching frequency of drones, while considering constraints on battery capacity and disconnection rate. By proposing a solution based on dynamic programming, this study provides reliable cargo drone trajectories and verifies the effectiveness of the method through simulation experiments. In addition, by evaluating the effects of multiple parameters such as cell network connectivity conditions and drone height, this study provides design guidelines for cargo drone operation.

Propose a heuristic solution for unmanned aerial vehicle (UAV) swarm scheduling in a one vehicle multi machine system. By analyzing the task allocation of multiple drones, it is possible to quantify the time savings brought by using multiple drones and reveal the potential diminishing marginal benefits that additional drones may bring.

However, even in the mode of one vehicle with multiple machines, it may not be able to meet delivery needs in certain situations. At this point, the collaborative mode of multiple machines and vehicles becomes the solution. In this mode, multiple vehicles and drones work together to form a massive distribution network. Vehicles can collaborate with each other to transport goods from one place to another; And drones can quickly deliver goods in the air, delivering them directly to their destination. This model can achieve a larger range of delivery and can flexibly adjust delivery strategies according to actual situations.

When implementing these collaborative models, it is also necessary to consider some key factors. For example, how to ensure effective communication and collaborative work between drones and vehicles? How to accurately schedule and manage drones? How to ensure the safety and reliability of the delivery process? These issues need to be addressed through technological innovation and reasonable management strategies.

Dangerous remote areas are often accompanied by harsh environments. Therefore, how to enhance the adaptability of UAVs in harsh environments has become an important factor to be considered in our scheme design. This paper can design a dust-proof and waterproof shell for them. This shell is made of special sealing materials, which can effectively prevent sand and rain from entering the interior of UAVs, and ensure that they can still work normally in severe conditions such as sandstorms and rainy days. DJI FlyCart 30, the latest logistics drone launched by DJI, adopts IP55 protection. In addition, attention will also be paid to the low temperature resistance performance of drones. By adopting advanced insulation materials and temperature control technology, we ensure that drones can start and fly normally in low temperature environments, without being affected by severe cold weather.

In terms of perception and avoidance technology, multi-sensor fusion techniques such as extended Kalman filtering will be adopted to improve the perception accuracy and real-time performance of drones towards the environment. By integrating multiple sensors such as LiDAR and visual cameras, drones will be able to more accurately identify and avoid obstacles, ensuring flight safety.

5. Conclusions

In summary, the drone cluster scheduling strategy is a complex and sophisticated system engineering that requires in-depth research and practical exploration in multiple aspects. With the continuous progress of technology and the expansion of application scenarios, we have reason to believe that drone cluster scheduling will play an increasingly important role in the future urban logistics field.

Based on the complex and dense population of cities, this article also needs to consider safety risk management. Establish a comprehensive safety management system, including flight regulations, safety inspections, and emergency plans, to ensure the safe and controllable flight of unmanned aerial vehicles. Strengthen communication and coordination with air traffic control departments to ensure that drone flights comply with relevant laws and regulations.

By implementing a reasonable drone cluster scheduling strategy and technology, this article can effectively address the challenges in urban low altitude takeaway delivery, improve delivery efficiency and service quality. In the future, with the continuous development and improvement of drone technology, drone cluster scheduling will play an increasingly important role in the field of urban logistics. Looking forward to seeing more innovation and breakthroughs, bringing more convenience and possibilities to urban low altitude takeout delivery.

Finally, in order to improve distribution efficiency and management level, regional distribution centers and transfer stations will be established. These facilities will be responsible for the distribution of materials, scheduling of drones, and tasks such as charging and replacing batteries, ensuring that drones can continuously complete distribution tasks. At the same time, by establishing a real-time monitoring system, the flight status, position, etc. of the drone can be monitored in real time to ensure the safety and controllability of the flight.

References

- [1] Zhang, S. & Zhang, R. Radio Map Based 3D Path Planning for Cellular-Connected UAV. Preprint at <http://arxiv.org/abs/1912.00021> (2020).
- [2] Zhang, S. & Zhang, R. Radio Map Based Path Planning for Cellular-Connected UAV. Preprint at <http://arxiv.org/abs/1905.05046> (2019).

- [3] C. Xiang, P. Hao and X. Zhang, "The Path Planning Study of Multi-task Logistics UAVs Under Complex Low Airspace," 2021 33rd Chinese Control and Decision Conference (CCDC), Kunming, China, 2021, pp. 5238-5242
- [4] H. Liu et al., "An Iterative Two-Phase Optimization Method Based on Divide and Conquer Framework for Integrated Scheduling of Multiple UAVs," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 9, pp. 5926-5938, Sept. 2021
- [5] N. Cherif, W. Jaafar, H. Yanikomeroğlu and A. Yongacoglu, "Disconnectivity-Aware Energy-Efficient Cargo-UAV Trajectory Planning with Minimum Handoffs," ICC 2021 - IEEE International Conference on Communications, Montreal, QC, Canada, 2021, pp. 1-6
- [6] S. Sawadsitang, D. Niyato, P. -S. Tan and P. Wang, "Joint Ground and Aerial Package Delivery Services: A Stochastic Optimization Approach," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 20, no. 6, pp. 2241-2254, June 2019
- [7] Wei Hechuan, Shi Jianmai, Liu Zhong, et al. Overview of unmanned aerial vehicle delivery models and path planning for the last mile delivery [J]. *Computer System Applications*, 2023, 32 (9): 1-18.
- [8] Yang Xu, Wang Rui, Zhang Tao. A review of intelligent optimization algorithms for path planning of unmanned aerial vehicle clusters [J] [2024 04 15]
- [9] Zhang Shixuan. Overview of the Development Status of Logistics Drones [J]. *Internal Combustion Engine and Accessories*, 2020 (8): 3
- [10] Li Dan. Overview of Path Planning Algorithms for Logistics Drones [J]. *China Storage and Transportation*, 2023 (1): 157-159
- [11] Geng Zengxian, Cheng Wenliang, Wang Zirui, et al. Research Review on Path Planning of Logistics Drones [J]. *Science and Technology Communication*, 2022, 14 (6): 4
- [12] D. Dissanayaka, T. R. Wanasinghe, O. De Silva, A. Jayasiri and G. K. I. Mann, "Review of Navigation Methods for UAV Based Parcel Delivery," in *IEEE Transactions on Automation Science and Engineering*, vol. 21, no. 1, pp. 1068-1082, Jan. 2024