Drone Delivery System for Takeaway Business

Project Proposal

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Contents

1. Introduction

1.1 Problem

We are going to design and realize an airway delivery system with drone, container, and cloud server. Delivery of light weight, medium range, fast response within a city is a strong demand especially during rush hour. Traditional airway delivery drones with GPS navigation are not precise enough for landing in limited space.

Existing delivery drones on the market usually require manual operation during picking and placing the goods, while our design aims to achieve the process automatically. Intelligent drones are still in the early progress of being developed. The market and application of drones are expanding rapidly, which proves that we are participating in a research field with a high demand.

1.2 Solution

The system we are going to construct can be divided into 3 subsystems due to the platform: Intelligent drone, ground-based terminal, and cloud server. All these subsystems are connected to each other by communication network and cooperate during the delivery tasks.

The first significant part is the drone subsystem. The drone carries a host computer which is responsible for autopilot of drone and the communication with the ground terminal. At the same time, the drone is equipped with RTK devices and GPS locator to achieve precise landing and path tracking. The structure of the drone is also designed for clamping delivery boxes and assisting to land precisely.

Secondly, the ground terminal subsystem with a landing platform and storage cabinets can provide the RTK signal for the drone and guide the drone to land precisely. The elevator and claws equipped on the terminal can achieve the function of receiving and sending deliveries.

The third component of the system is the server and APP for data processing and task planning. The other subsystems can communicate with the server all the time during the delivery task by wireless network. The cloud server is responsible for managing the information from the clients and the system devices and giving the command to them.

1.3 Visual Aid

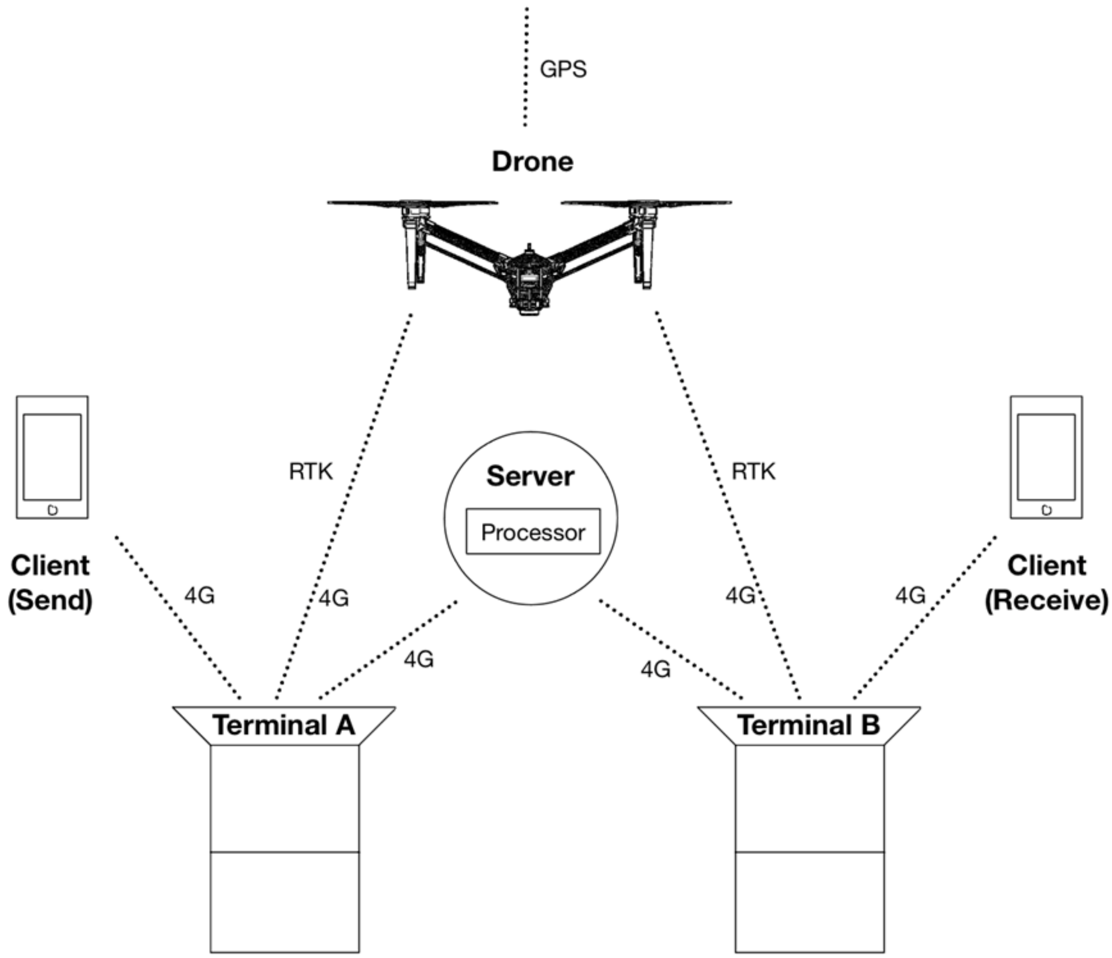

Figure 1. System View Aid Diagram

1.4 High-level requirements list

- TOW (Take-off Weight) of the drone is under 4kg while MTOW (maximum Take-off Weight) is above 8kg, where the max load is about 4kg.
- Max diagonal size of the drone is restricted below 1.2m with 12m range active obstacle avoidance.
- Flight endurance at maximum load longer than 8min, so that be able to reach 4km at the maximum speed of 30km/h in a single flight.

2 Design

2.1 Block Diagram

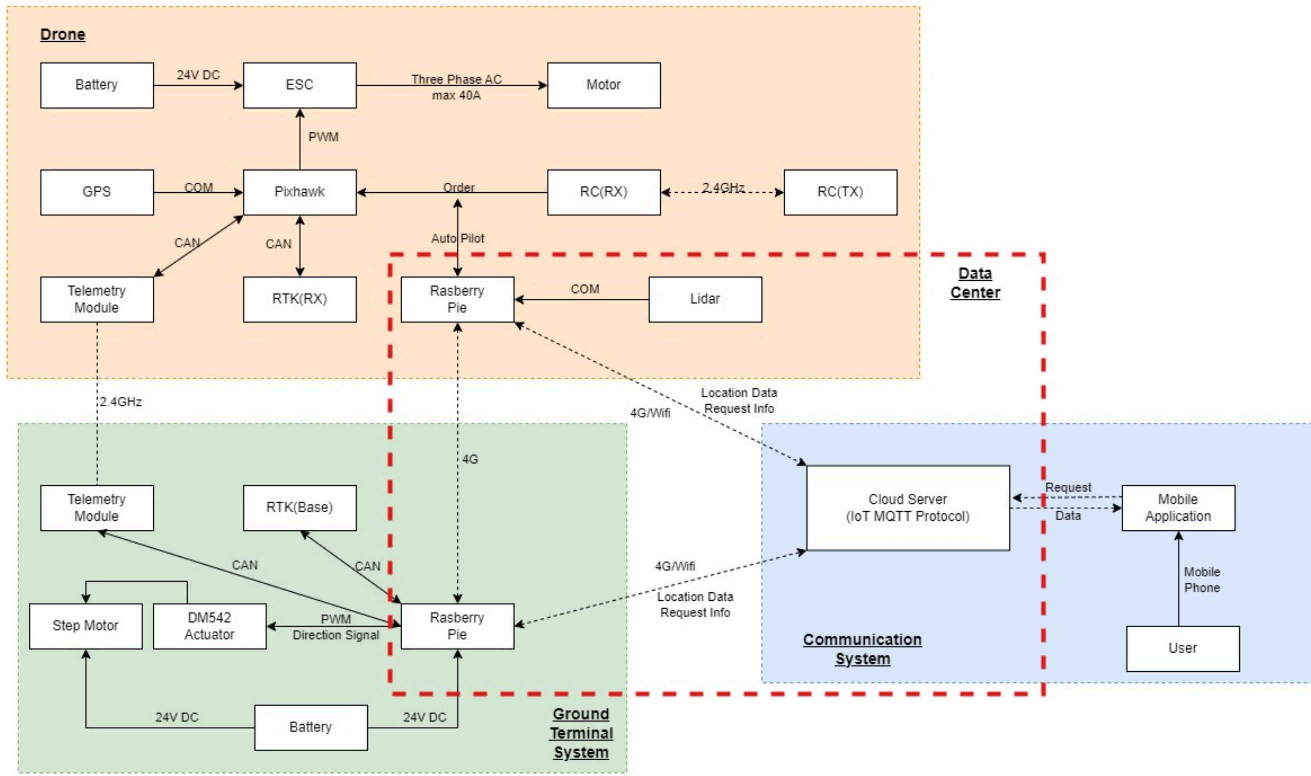

Figure 2: Overview Block Diagram

2.2 Subsystem Overview and Requirements

2.2.1 Drone Subsystem

The drone is designed to execute flight tasks for delivery without manual assistance within urban areas. To achieve 2km distance and 4kg load each single flight, the drone has 8kg MTOW and 10min endurance at the condition. The structure of the drone is specially designed for grabbing the delivery box and landing on a restricted area field. The skeleton of the drone has a controllable angle transform during the flight. The landing legs can be raised high enough to avoid blocking the radar and the delivery box. All the transformation is driven by one motor with parallelogram structure. The drone is also equipped with computers and radar for active obstacle avoidance.

For the above functions, below are the detailed requirements.

- Quadrotor dynamical system consists of four 6S, 340KV, 4110 motors with 17’ propeller and ESC.
- Batteries with voltage between 21.0~25.2V and capacity above 9000mAh in total.
- Carbon fiber resin composite and Nilon printed primary structure.
- DTOF radar with range of 12 meters and precision of 30mm for obstacle avoidance.
- 2.4GHz S.BUS signal remote control between ground terminals and pilot.

2.2.2 Ground Terminal Subsystem

This subsystem consists of a lift-and-load mechanism and shelves, while the shelves consist of a top helipad to land drone, and two storage cabinets. For the guest end, goods are delivered to the helipad by drone and then placed into the corresponding cabinets by the lift-and-load mechanism. For the merchant end, goods are removed from the cabinets by the lift-and-load mechanism and transported to the top helipad for drone retrieval. The lift-and-load mechanism has two degrees of freedom, both achieved through timing belt drives for vertical (z-direction) and horizontal (x-direction) movements. Goods are picked up through gravity locking, which involves extending support rods into grooves below the goods, lifting them by upward movement, and then retracting the rods to move goods onto the platform. The process of placing goods down is the reverse of the pickup process.

For the above functions, below are the detailed requirements.

- One stepper motor that could provide 3.0 N*m torque to lift the platform and good.
- One stepper motor that could provide 1.0 N*m torque to move the support rods.
- Two sets of sliding rail - timing belt linear motion device. One set could achieve 1200mm movement range (Z-axis) while the other could achieve 500mm movement range (X-axis).
- A Raspberry Pi controller used to program and control the drive motor.
- A portable power supply with a capacity of 20000mAH and 24V DC output, serving as the power source for the motor (ensuring 5 hours of operation).

2.2.3 Communication Subsystem

This subsystem is responsible for the communication between the devices, for example how drone would know the destination, how the sender would tell the drone to pick up the goods, how the receiver would know the delivery progress and so on.

For the above functions, below are the detailed requirements.

- A cloud server to handle all the requests and data transfer.
- An application (Android) to both send request and show progress.
- Raspberry Pi in ground terminals to receive data from server and interpret it to the drone.
- Raspberry Pi in drone to send detailed location data to ground terminal and server.

2.3 Tolerance Analysis

The calculation of the drone is mainly about dynamics and power requirements. The mass of the drone skeleton is restricted to 4kg, and the load is expected to be larger than 8kg. Considering the extreme conditions, we chose four motor sets with 2.1kg thrust each. The capacity of the battery we use is about 5000mAh and the power calculated when hovering with maximum load is 1600W, which yields the endurance is 4.7min loaded 4.6kg. The distance that could be reached in a single flight is expected to be above 3km, while the power supply will fail according to the computation above. The solution we found is to add another set of batteries, resulting in 10min endurance loaded 4.2kg, which is acceptable for the delivery tasks.

3. Ethics and Safety

According to ACM Code of Ethics and Professional Conduct, “respect privacy” and “honor confidentiality” should be considered. On the one hand, we will focus on the data security of the app and communication to avoid data breach; on the other hand, when collecting data to navigate during the flight, we will ensure that the data only be used to determine the path. Also, due to the characteristics of UAV, we will apply for permission to operate the drones and make sure that it is allowed to fly in certain locations. This will satisfy the term “Maintain high standards of professional competence, conduct, and ethical practice” and “Know and respect existing rules pertaining to professional work.” In the code, “Recognize and take special care of systems that become integrated into the infrastructure of society” should be considered as well. Since our design aims to be used in delivery and may occupy public space, we may have to make rules to ensure that our system won’t be used improperly. For example, we may have to check what is to be delivered before we take the order.[1]

Meanwhile, there are also several potential safety concerns need to be addressed in our project. First, it’s essential to implement precise navigation and collision avoidance systems, to avoid collision and falling risks. Second, drones equipped with cameras could capture images of individuals without their consent, which has potential privacy concerns. There are also Federal Regulations for drone operation, which are necessary to consider and follow. “Small Unmanned Aircraft Systems (UAS) Regulations (FAA Part 107) [2]” regulated the detailed rules for the operation of drones weighing less than 55 pounds including guidelines on operator certification, operational limitations, and airspace restrictions. Each drone should be equipped with Remote ID technology.

References

[1] "ACM Code of Ethics and Professional Conduct," Association of Computing Machinery, June 22nd, 2018. Available at https://www.acm.org/code-of-ethics

[2] "Small Unmanned Aircraft Systems (UAS) Regulations (Part 107)" Federal Aviation Administration, October 6, 2020. Available at: https://www.faa.gov/newsroom/small-unmanned-aircraft-systems-uas-regulations-part-107