A Survey on Route Planning Drone Based Delivery Systems

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Abstract: The traffic conditions on our already excessively clogged urban streets are greatly worsened by the growing demand for urban delivery services. The lack of suitable parking spaces available for effective offloading operations exacerbates the issue even more. Consequently, there has been a sharp increase in interest in investigating environmentally friendly substitutes for conventional logistics based on trucks. Drone technology has the ability to greatly reduce the need for vehicles in metropolitan areas and enable broad home delivery services. The development of drone-based delivery systems that are inexpensive and quickly deployable has piqued the interest of both industry and academia. This work offers a thorough analysis of drone-based delivery systems as they are right now. It examines the most recent developments, approaches, and tools used, with a focus on job scheduling optimization and creating effective routes for drone delivery. It contributes a comprehensive classification based on essential system criteria, such as fleet composition, degree of device collaboration, and supporting infrastructure, and critically evaluates the benefits and drawbacks of current solutions.

Keywords—Drone delivery, drone route planning.

I.INTRODUCTION

We selected recent works addressing drone routing problems applied to parcel delivery; we focused on those in which drones are expected to accomplish deliveries autonomously and without relying on additional ground vehicles, such as trucks and public transportation. In this study, we analyze existing research on drone delivery systems (DDSs), focusing on the specific issue of task assignment and trajectory planning, i.e., assigning deliveries to drones and determining the optimal paths for drones, respectively. We provide a novel classification for DDSs, considering the number of drones involved, the volume of delivery demands, and the supporting infrastructure (such as depots and support stations).

This is the first attempt, as far as we are aware, to categorize this kind of system. Our goal is to offer insightful viewpoints for upcoming studies that highlight open research difficulties.

1) It offers a description of system components and suggests a novel classification based on such infrastructures; it thoroughly reviews the most recent literature addressing route planning and task assignment for drone delivery systems and identifies the challenges related to drone delivery modelling and the objectives of interest for assessing a drone delivery service.

2) It examines industry-adopted solutions, highlighting the expanding interest in this sector.

3) It offers a succinct synopsis of many topics of beyond drone route planning that have been researched in the literature, such as contemporary delivery systems that employ additional technologies to complement drone technology.

II.CLASSIFICATION

We use four kinds of techniques, which vary in terms of the quantity of delivery demand and the number of drones, to categorize the literature on route planning for delivery systems: 2) Multiple Drones Multiple Deliveries; and 3) Single Drone, which is further separated into Single Delivery and Multiple Deliveries. Depending on the infrastructure that the delivery services rely on, each class can be further broken down into three sub-categories: Single Depot, Multiple Depot, and Support Stations.

III. SYSTEM COMPONENTS

Prior to exploring the various classes, we outline the system's components and provide definitions for some terms:

• Parcel: a shipment that needs to be sent. Its weight and size may be limited by design decisions or technical requirements.

• Drones: a mode of transportation for completing deliveries. Drone constraints, such as those related to payload capacity, flight speed, range, battery management, etc., are carried over to DDSs. Drone coordination needs to be taken into consideration and managed if the DDS depends on a fleet of drones.

• Support Station: a decentralized organization placed in the targeted area with the purpose of aiding drones in their operations. It may be necessary to deploy multiple support stations in order to create a transportation network.

Depot: a central location set aside to support drone activities, such as enabling parcel on-board loading and battery repair or recharging. Additionally, unlike support stations, the depot allows for the storage of packages rather than the direct pickup of packages by recipients. Additionally, unlike support stations, which serve as intermediate pit stops, drone routes begin and end at the depot.

Supplier: a warehouse where drones are used to load and unload packages. It doesn't offer support for drones.

• Customer: the person or organization wishing to ship or receive the package.

A.SINGLE DRONE

In this section, we describe drone-delivery solutions considering a single drone.

1) SINGLE DELIVERY

Planning a single path to fulfill a single delivery request is the issue that the single drone delivery scenario attempts to solve. This situation has only been examined in one depot infrastructure, as far as we are aware.

Therefore, from a routing perspective, solving this problem is straightforward and just requires calculating the trajectory from the depot to the customer's position and back.

The ability of the drone to fly to a specific location is the only remaining issue, assuming all other concerns are resolved (such as uncertainties resulting from environmental circumstances or drone malfunctions).

(b) DDS handling multiple deliveries with multiple drones that rely on an infrastructure made of a single depot.

DDS handling multiple deliveries with multiple drone that rely of single depot with some suppliers.

(c) DDS handling multiple deliveries with multiple drones that rely on an infrastructure made of a single depot and some suppliers.

2) MULTIPLE DELIVERIES

The intended route must satisfy several delivery requests if a single drone is doing several deliveries. One package at a time or several at once might be loaded onto the drone.

The drone route may consist of one trip in the first scenario and multiple trips in the second. Most of the works that address issues that fall into this category suggest using a single-depot infrastructure for their systems.

a: SINGLE DEPOT

The objective is to determine a path that leaves the depot, travels to every client, and returns to the depot in the shortest amount of time. Given that a drone can carry many packages, it's critical to take into account how the weight of the packages may impact the drone's operation. This essay examines how a drone's cargo affects the speed at which it can fly.

To derive an equation that represents speed as a function of payload given the drone's driving force and velocity without a payload. It is believed that the combined weight of the packages is less than the drone's carrying capability. Limitations on battery life and energy usage are not taken into account. To provide a Dynamic Programming approach to address the optimization issue. Studies are carried out using artificial data.

b: SUPPORT STATIONS

The literature takes into account support stations but not multiple depots for the single drone scenario. When taking into account energy constraints, this enables drones to go great distances. We present a multi-objective issue with the goal of reducing both delivery time and energy consumption. In order to achieve this, two requirements must be met: drones cannot fly over no-fly zones in metropolitan areas, and they must return to a support station to securely replenish their batteries or fuel if they run out of energy to reach the next customer. The authors use a metaheuristic that combines the Multi-Objective Variable Neighbourhood Descendent (MOVND) and Greedy Randomized Adaptive Search Procedure (GRASP) methods to address this issue.

C. MULTIPLE DRONES MULTIPLE DELIVERIES

The multiple drones multiple deliveries is the most complex scenario and also the most addressed in the literature. Typically, each delivery is assigned to a single drone, which has to carry the parcel from the source to the destination. Cooperation among drones, allowing parcels to be exchanged between drones, has been proposed only in two articles [28], [30]. The fleet of drones may be made of identical drones (i.e., homogeneous fleet), or made of drones with different specifications such as payload capacity, battery capacity, size etc. (i.e., heterogeneous fleet). We group together works depending on whether they consider homogeneous or heterogeneous fleets. For this scenario, the literature proposes different setups, which include: i) single depot, ii) multiple depots, iii) presence of support stations, and iv) mixed.

2) HETEROGENEOUS FLEET

The salient features for works addressing Multiple Drones Multiple deliveries with a heterogeneous feet of drone.

a: SINGLE DEPOT

Drones take off and land at the base depot, where their cargo can be expanded to the maximum amount. Drone energy consumption is not predicted, and no energy constraints are taken into account. Reducing the so-called Expected Loss of Demand (ELOD) resulting from drone malfunctions—which are thought to be exponentially distributed over time—is the main goal. The average weight of the lost requests at the time of a failure is known as ELOD. The proposed approach is articulated as follows: the first stage finds a set of feasible solutions for a drone scheduling problem; then, for each route, the ELOD metric is computed; f inally, the subset of feasible routes with minimum ELOD covering all customers is selected.

b. Multiple Depots

the challenge of optimizing the number of completed deliveries while reducing the distance traveled in a delivery system made up of a diverse fleet of drones and equipped with several depots. Delivery requests are modeled as jobs for drones to do. Every task is associated with a distinct demand, which is identified by the delivery point's coordinates. Drones need several depots in order to load packages and replenish their batteries. The writers make the assumption that the amount of time required to recharge the battery is fixed and unaffected by its level of charge.

It is more appropriate to make this assumption while replacing batteries.

Each route that begins and finishes at a depot can have more than one drone serving consumers. Each drone has a restricted payload that it can carry while completing its designated activities.

c: SUPPORT STATIONS

The suggest a drone delivery system that separates the sky into two layers: a lower layer that covers low altitudes and an upper layer that covers high altitudes. The authors take into account a heterogeneous flock of drones that can fly in either the upper or bottom layer based on their size. Larger drones that are intended to carry greater loads are designated for the upper layer, while smaller drones that are capable of carrying lighter loads are designated for the lower layer. Drones are dependent on a network of non-capacitated support stations for transit in order to recharge their batteries. Drones also use some support stations to transfer packages between tiers. Drones must transport or retrieve packages from dispersed customers in random areas.

In the second example, the lower layer, 10 packages from the higher layer that were delivered to the support stations, and an additional 15 packages are taken into account. Each stratum has a total of five support stations set up. Three stations act as exchange points between layers and are located at predetermined locations. Two stations are placed at random locations and are used only for charging. A multi-objective function is taken into consideration, and 64 weight combinations are thought to provide MILP issues. The authors examine the connection between the goals and come to the following conclusions: 1) reducing the last collection subsequently reduces the last delivery; 2) completing the mission with more charged batteries is associated with traveling farther; and 3) if more drones are used, the mission completion time decreases.

- What are the objectives of the proposed approaches?
  - ⟶ Time
    - ⟶ Delivery Time (minimize)
    - ⟶ Makespan of delivery times (minimize)
    - ⟶ Lateness (minimize)
    - ⟶ Reward for on-time delivery (maximize)
  - ⟶ Cost
    - ⟶ Drone Purchase costs (minimize)
    - ⟶ Drone Deployment (minimize)
    - ⟶ Energy Consumed (minimize)
    - ⟶ Penalty costs (minimize)
    - ⟶ Recharging costs (minimize)
    - ⟶ Loss due to drone failure (minimize)
  - ⟶ Resource Utilization
    - ⟶ Number of used drones (minimize)
    - ⟶ Unserved zones (minimize)
  - ⟶ Distance
    - ⟶ Makespan of traveled distances (minimize)
    - ⟶ Overall traveled distance (minimize)
  - ⟶ Delivered parcels
    - ⟶ Amount (maximize)
    - ⟶ Percentage (customer satisfaction level) (maximize)
  - ⟶ System Reliability
- How are drone energy limitations modeled?
  - ⟶ Maximum Flight Time
  - ⟶ Maximum Flight Distance
  - ⟶ Battery Capacity
  - ⟶ Energy consumption model, considering ...
    - ⟶ Payload Weight
    - ⟶ Drone Weight
    - ⟶ Battery Weight
    - ⟶ Drag Force
    - ⟶ Wind
    - ⟶ Other
- Which and how are the uncertainties handled?
  - ⟶ Wind
    - ⟶ Constant speed and direction
    - ⟶ Changing speed and direction
  - ⟶ Drone Failure
    - ⟶ Flying
    - ⟶ Taking off

CHALLENGES OF DRONE

IV CONCLUSION

This survey reviews several articles addressing the problem of route planning in Drone Delivery Systems. We have organized the reviewed articles according to a novel classification that takes into account the system infrastructure, the fleet size and the volume of the delivery demand. For each work, we have summarized the problem addressed, the solution proposed, and the obtained results. Moreover, we have outlined how the solutions presented in the reviewed articles tackle challenges common to all the proposed DDSs, such as the objectives of the models and algorithms that have been proposed, the energy limitations of battery-powered drones, and whether any uncertainty is handled. Moreover, despite the growing research interest and the number of Drone Delivery Systems available in the academic literature, it seems there is a lack of real-field experiments, owing to the fact that flying a drone or a fleet of drones over urban areas requires patents and permissions from the local authorities. Some studies have, however, made significant strides by incorporating real-world data into their simulations. This has provided valuable insights into drone delivery systems' capabilities and limitations.

In conclusion, drones represent a promising, environ mentally friendly technology that can be exploited in many application scenarios. Delivery systems are moving toward this technology, and a few services and trials have been successfully implemented worldwide. Therefore, it is reasonable to believe that this will continue to be an essential area of applied research in the years to come.

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