

On a Mathematical Model for a New Drone Routing Problem

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ABSTRACT

A new Drone Routing Problem for Delivery is studied. The problem considers a delivery system with a depot for a fleet of drones, a set of customers, and a set of facilities where the drones pickup products. An order from a customer could include several copies of an item or different items that the drone can support. Since the customer order could not be completed in one facility, more than one of these could be visited to complete the order. The Drone Routing Problem with Several Pickups in the Facilities (DRPPF) aims to satisfy customer orders by minimizing the makespan. An optimization model is proposed for the problem, a set of problem instances of different structures is created, and experiments are conducted with the model. The experiments illustrate the results by using CPLEX to run the mathematical model. A metaheuristic GRASP was implemented to obtain feasible solutions for larger instances.

KEYWORDS. Drone routing problem. MILP formulation. Distribution logistics.

Paper topics. LT, OC

1. Extended Abstract

Unmanned Aerial Vehicles (UAVs), also known as Drones, have played an important role in different operations of delivery and surveillance in the last years. Several papers have presented a broad spectre of applications and several journals have surveyed these advances in review papers, [Rojas-Viloria et al., 2021], [Otto et al., 2018]. Closer to this study, some reviews have presented problems, models, algorithms, and applications for the participation of drones in delivery operations, [Macrina et al., 2020] [Moshref-Javadi and Winkenbach, 2021]. In the context of last-mile delivery, a new problem is defined, and the formulation of mixed integer linear programming (MILP) is developed. The problem, called the Drone Routing Problem with Several Pickups in the Facilities (DRPPF), considers a delivery system when there is a depot for a fleet of drones, a set of customers, and a set of facilities where the drones pickup products to fly to the customers. An order from a customer could include several copies of an item or different items that the drone can support. Since the customer order could not be completed in one facility, more than one of these could be visited to complete the order. DRPPF aims to satisfy all the customer orders minimizing the makespan. The problem has application in a context where the products ordered by the customers are distributed in several facilities located in the studied region. A special case of the DRPPF considers that the facilities have an unlimited inventory of products. Therefore, each drone pickups all the products in only one facility [Gómez-Lagos et al., 2022]. So, in the generalized variant of the problem, DRPPF, a new layer is added by the path followed by the drones to complete the customer order. This layer creates a new component in the mathematical model that integrates the path of pickups with the route of each drone.

Figure 1 shows an example of a DRPPF. Figure 1a illustrates a DRPPF network with a depot (d), three facilities (f_1 , f_2 , and f_3), and seven customers ($c_1, \dots, c_7$). The size of the drone fleet is three. Note that this input network is mixed, meaning it contains directed and undirected links. In more detail:

- There is a directed link from d to every node f .
- There is a directed link from every node c to d .
- There is a bidirected link between every node f and every node c .
- There is a bidirected link between each pair of nodes f .

Figure 1b displays a portion of a feasible solution (the routing component) for the problem, where each drone's route is color-coded. Drone 1's route (green) is: $d - f_1 - f_2 - c_3 - f_2 - f_1 - c_1 - f_1 - c_2 - d$. Drone 2's route (blue) is: $d - f_2 - f_3 - c_5 - f_2 - c_4 - d$. Drone 3's route (red) is: $d - f_3 - c_7 - f_3 - c_6 - d$.

We have implemented the mathematical model for the DPPRF by using the CPLEX solver. Several combinations of the number of customers, number of facilities, and size of the drone fleet are considered. The results show that from the combination of 10 customers, 5 facilities, 3 drones, and 20 products, CPLEX is not able to find optimal solutions. Therefore, a GRASP metaheuristic was implemented which can find good feasible solutions, in low computational times, for different combinations of instances. The large instance solved by GRASP contains 20 customers, 7 facilities, 5 drones, and 40 products. Details about the mathematical formulation, the GRASP metaheuristic, the set of instances generated, and the complete results, will be presented in the conference.

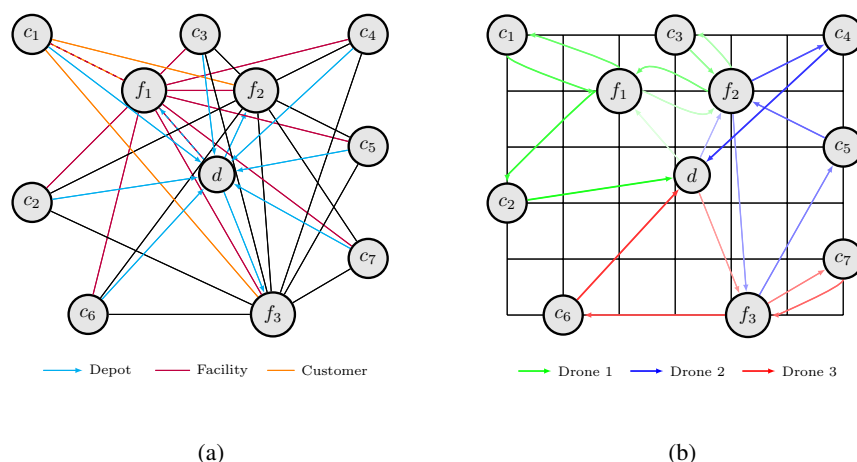


Figure 1: A DRPPF network is shown in (a), and a feasible solution using three drones is shown in (b)

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