Drone-Assisted Parcel Delivery in Presence of Micro-Depots

Mahdi Moeini[1], Daniel Schermer[1], Oliver Wendt[1]

BISOR, Technische Universität Kaiserslautern, Gottlieb-Daimler-Straße, 67663 Kaiserslautern, Germany

{mahdi.moeini,daniel.schermer,wendt}@wiwi.uni-kl.de

Mots-clés : *Logistics, Traveling Salesman Problem, Drone, Mixed Integer Program.*

1 Introduction

Civil drones have been used since many years ago in different sectors, e.g., energy, agriculture, surveillance, and emergency response. However, in recent years, many commercial logistic companies such as Amazon, DHL, DPDgroup, etc. have started conducting experiments with the objective of using drones in last-mile logistics, i.e., delivering parcels to the customers [1, 3, 4, 5].

In fact, traditional package delivery systems use conventional transport vehicles, e.g., trucks, cars, or motorcycles for delivering parcels. However, due to growing popularity of e-commerce and importance of fast delivery in satisfaction of the customers, drones attracted attention as an alternative and novel mode of delivery. In comparison to the usual modes of delivery, e.g., trucks, drones might be less reliable but more cost-efficient. Furthermore, drones are considered as a faster mode of delivery as they are not restricted to the road network, traffic jam, and red lights. Consequently, drones are also useful in delivering parcel in areas that are difficult to reach. Finally, drones consume less energy than trucks; hence, drones might be considered as more environment-friendly delivering tools.

Following the practical motivations, many researchers started examining integration of delivery by drones in the classical models, e.g., traveling salesman problem with drone (TSP-D) [1, 2] and vehicle routing problem with drones (VRPD) [4, 5, 7].

Drones are not the sole novelty of technology in parcel delivery. Automated transport/ground vehicles (ATV/AGV) are also considered as a new mode of parcel delivery. Indeed, ATVs have almost the same advantages as drones except the fact that ATVs are slower than drones; however, ATVs are safer and more cost and energy efficient than drones. Consequently, ATVs might be considered as an even more reliable delivery mode in dense urban areas.

In this study, we use classic as well as innovative concepts and establish a new framework that uses the traditional delivery modes, e.g., trucks, along with new delivery vehicles, i.e., drones and ATVs. More precisely, we are interested in a variant of the Traveling Salesman Problem (TSP) in which, in addition to a truck, a drone and a set of robots (as ATVs) are also used to bring parcels to customers. The drone assists the truck for serving customers, but the robots (ATVs) deliver parcels through round-trips from so-called *micro-depots* (e.g., DHL packet stations). This framework that combines truck, drone, and robots is called the *Drone-Assisted Traveling Salesman Problem with Robot Stations* (TSP-D-RS) [6].

2 Description of the problem and the results

As it is illustrated in Figure 1, the TSP-D-RS aims at finding a valid truck route connected with feasible utilization of the drone and robots such that, by the end of the mission, all customers are served and minimal delivery time or cost is achieved. In fact, through the TSP-D, assisting the truck by a drone reduces the makespan and by using the TSP-D-RS, we can

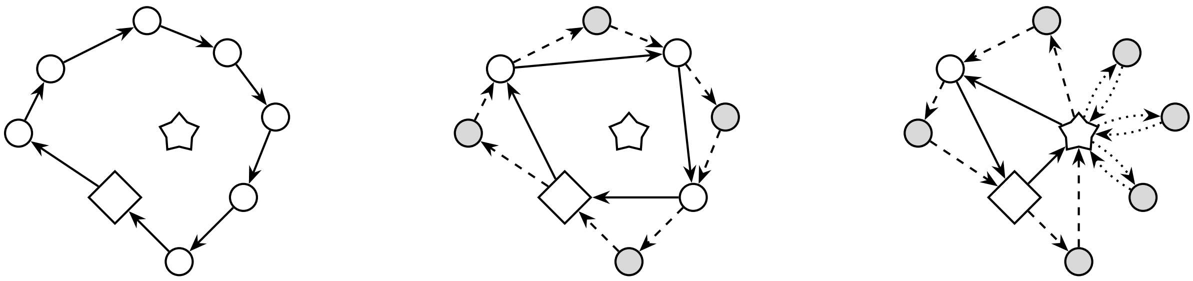

FIG. 1 – An illustration of TSP, TSP-D, and TSP-D-RS solutions (from left to right): the paths of the truck, drones, and robots are indicated by solid, dashed, and dotted lines, respectively. In each figure, the depot and micro-depot are indicated by the square and star shapes; however, the robots may only be utilized in the TSP-D-RS.

execute parallel deliveries by means of three types of delivering vehicles, which shortens further the mission time.

We formulate the TSP-D-RS as a mixed-integer linear programming (MILP) problem, which can be solved by any standard MILP solver, e.g., Gurobi Optimizer or IBM CPLEX. In order to emphasize the benefits of using a mixed fleet of truck-drone-robots, we generated random instances and solved the MILP formulation of the TSP-D-RS by Gurobi. According to the numerical results, using combined fleet can reduce the delivery time and the total cost. Moreover, we show that minimizing the mission time reduces also the operational costs. However, optimizing the costs might generate an optimal solution that increases the mission time.

Références

[1] Niels Agatz, Paul Bouman, and Marie Schmidt. Optimization approaches for the traveling salesman problem with drone. *Transportation Science*, Vol. 52(4): 965–981, 2018.

[2] Chase C. Murray and Amanda G. Chu. The flying sidekick traveling salesman problem: optimization of drone-assisted parcel delivery. *Transportation Research Part C: Emerging Technologies*, Vol. 54: 86–109, 2015.

[3] Alena Otto, Niels Agatz, James Campbell, Bruce Golden, and Erwin Pesch. Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: a survey. *Networks*, Vol. 72(4): 411–458, 2018.

[4] Daniel Schermer, Mahdi Moeini, and Oliver Wendt. A hybrid VNS/Tabu search algorithm for solving the vehicle routing problem with drones and en route operations. *Computers & Operations Research*, Vol. 109: 134–158, 2019.

[5] Daniel Schermer, Mahdi Moeini, and Oliver Wendt. A matheuristic for the vehicle routing problem with drones and its variants. *Transportation Research Part C: Emerging Technologies*, Vol. 106: 166–204, 2019.

[6] Daniel Schermer, Mahdi Moeini, and Oliver Wendt. The drone-assisted traveling salesman problem with robot stations. *Proceedings of the 53rd Hawaii International Conference on System Sciences (HICSS)*, pp. 1308–1317, 2020. http://hdl.handle.net/10125/63900

[7] Xingyin Wang, Stefan Poikonen, and Bruce Golden. The vehicle routing problem with drones: Several worst-case results. *Optimization Letters*, 11(4): 679–697, 2016.