Multi-Objective Optimization Algorithm With Adaptive Resource Allocation for Truck-Drone Collaborative Delivery and Pick-Up Services

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***Abstract*— To efficiently implement the truck-drone collaborative logistics system, we introduce a multi-objective truck-drone collaborative routing problem with delivery and pick-up services (MCRP-DP). A truck collaborating with a fleet of drones serves three types of customers that require delivery, pick-up, and simultaneous delivery & pick-up services, respectively. Different from most of the existing studies where the drone visits only one customer in a flight, we allow the drone to serve another customer requiring pick-up service when it completes a delivery service. Meanwhile, we simultaneously optimize three objectives: transportation costs, waiting time of vehicles (i.e., truck and drone), and service reliability. To solve MCRP-DP, we propose an objective space decomposition-based multi-objective evolutionary algorithm with adaptive resource allocation (ODEA-ARA). In ODEA-ARA, an objective space decomposition strategy is used to maintain the diversity while an adaptive resource allocation strategy is designed to improve convergence. We design an ensemble of relative improvement and relative contribution to assist the resource allocation and a variable neighborhood Pareto local search integrating 7 problem-specific neighborhood structures to improve the solution. Extensive computational experiments are carried out to evaluate the performance of ODEA-ARA. The experimental results show that ODEA-ARA outperforms its competitors. Meanwhile, several useful managerial insights are presented.**

***Index Terms*— Logistics, delivery and pick-up services, truck-drone collaboration, vehicle routing problem, multi-objective optimization algorithm, local search.**

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I. Introduction

THE truck-drone collaborative delivery system has attracted much attention in recent years [1], [2]. In this system, while a truck provides logistics services to customers, drones also can be used to serve nearby customers simultaneously. This system combines the advantages of trucks and drones while eliminating some of their shortcomings. For example, drones can deliver faster than trucks since they are not limited by road conditions such as traffic congestion. Meanwhile, drones are less expensive to maintain compared to traditional trucks [3], [4]. Thus, drones can be used to assist the small parcel logistics of trucks. On the other hand, the truck can act as a mobile platform to supply fresh batteries to drones to overcome the limitations of drones caused by short flight endurance and low capability. Therefore, the collaborative delivery system can further improve the efficiency of logistics [5], [6].

Several industrial companies have been competing to be the first to implement the truck-drone collaborative delivery system. For example, Mercedes-Benz has started a pilot project in Zurich to test their van and drone-based system for on-demand delivery of e-commerce goods [7]. UPS has designed the Horsefly system that integrates a 4 rotor drone that can fly fully autonomously with an electric delivery truck [8]. On the other hand, the academic community has been showing more interest in operational challenges, especially in optimizing the delivery routes of the system [2]. Murray and Chu [6] proposed the flying sidekick traveling salesman problem (FSTSP), which is commonly known as the first study that investigates the truck-drone collaborative routing problem. Thereafter, numerous studies were published by extending the FSTSP with more complex constraints, such as considering time windows [9], [10], [11], allowing a truck collaborates with multiple drones [12], [13], [14], etc.

In particular, most of the existing studies assume that a drone returns to the truck or depot once it accomplishes a delivery task. However, the drone still has the capability to serve other customers after dropping a parcel, which yields a possibility that can further improve logistics efficiency by allowing the drone to visit multiple customers in a flight. Few studies have recognized this possibility and formulated the problem as a multi-visit delivery problem [5], [15].