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Towards enhancing the last-mile delivery: An effective crowd-tasking model with scalable solutions

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ABSTRACT

In urban logistics, the last-mile delivery from the warehouse to the consumer's home has become more and more challenging with the continuous growth of E-commerce. It requires elaborate planning and scheduling to minimize the global traveling cost, but often results in unattended delivery as most consumers are away from home. In this paper, we propose an effective large-scale mobile crowd-tasking model in which a large pool of citizen workers are used to perform the last-mile delivery. To efficiently solve the model, we formulate it as a network min-cost flow problem and propose various pruning techniques that can dramatically reduce the network size. Comprehensive experiments were conducted with Singapore and Beijing datasets. The results show that our solution can support real-time delivery optimization in the large-scale mobile crowd-sourcing problem.

1. Introduction

Cargo transportation via rail networks and container ships is considered as the most cost-effective manner in urban logistics. However, when the goods arrive at the high-capacity warehouses, they must then be transported to the final destinations. This last leg of the supply chain is less efficient and comprises up to 28% of the total delivery cost.[1] Worse still, most consumers are not present when the deliveries are made. The unattended parcels may require multiple times of attempt-delivery and have become a significant issue among logistic companies.

To mitigate the situation, the concept of pop-station (pick-own-parcel station) has been adopted by some logistic companies such as Singapore Post.[2] The idea is that the parcels are directly delivered to the pop-stations. Then, consumers will be notified and collect their own parcels via mobile apps. If a parcel is not collected within 5 days,[3] it is considered as a failed delivery. To ensure that the model works, it requires expensive infrastructure costs because a large number of pop-stations have to be built to benefit residents in different areas of the city and minimize their walking distance for self-collection. In addition, the problem of reducing the parcel turnaround time for fast delivery is not well solved in this model. Many parcels may be kept in the lockers of pop-stations for several days.

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[1] https://en.wikipedia.org/wiki/Last_mile.
[2] https://www.mypopstation.com/.
[3] https://www.mypopstation.com/faqs#faq-02-06.

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In this paper, we investigate how to utilize the power of crowd-workers to enhance the last-mile delivery. In particular, we treat the delivery job of each parcel from its pop-station to the consumer as a crowd-task. A certain amount of money will be rewarded to a worker for the delivery according to the additional travel cost from his/her historical trajectory patterns. Our objective is to assign all the parcels in the pop-stations to the most convenient workers so as to minimize the total reward paid by the logistic companies. The underlying principles are similar to other sharing-economy applications to maximize the resource (crowd-worker in this application) utilization. With the availability of a large pool of citizen crowd-workers, the infrastructure expenses can be cut down as the crowd-delivery model requires much fewer number of pop-stations than the model of self-collection. In addition, both the parcel turnaround time and failure rate can be significantly reduced because the crowd-workers are more active in collecting the parcels and delivering them to the consumers.

Since there could be a huge number of parcels and workers in an urban city, our crowd-delivery model is essentially a large-scale assignment optimization problem. Our solution is to model it as a network min-cost flow problem and use it as the baseline for performance evaluation. Then, we propose various effective pruning strategies that can significantly reduce the network size. Comprehensive experiments were conducted with Singapore and Beijing datasets. The results show that after the network reduction, the performance achieves a speedup by 2–3 orders of magnitude. It takes less than 10 s to find the optimal assignment of 2000 parcels to a pool of 500,000 crowd-workers.

To sum up, the contributions of the paper include:

- We formulate an interesting crowd-logistics optimization problem that utilizes a large pool of citizen workers to perform the last-mile delivery.
- We formally show that the proposed model is equivalent to the network min-cost flow problem.
- We propose three types of pruning rules that can significantly reduce the network size, and hence improve the performance.
- We conduct comprehensive experiments using Singapore and Beijing datasets to verify the efficiency of our proposed methods.

The rest of the paper is organized as follows. We present the problem definition in Section 2 and review related literature in Section 3. The problem is formally reduced to a minimum cost flow problem in Section 4. Various pruning techniques are proposed in Section 5 to significantly reduce the network size. We conduct an extensive performance study in Section 6 to evaluate the performance of our proposed solutions. Section 7 concludes the paper with future work.

2. Problem definition

2.1. Background

In our crowd-delivery model, there are a bunch of pop-stations distributed around the city and a large pool of workers who are ready to accept the delivery tasks from pop-stations to the consumers' addresses. As shown in Fig. 1, we can split the city into voronoi cells according to the locations of pop stations. The logistic companies only need to be focused on the scheduling optimization of delivering parcels to the pop-stations. Intuitively, each parcel will be sent to the nearest pop-station according to its consumer's address. In other words, the final delivery address and the associated pop-station will be located within the same voronoi cell. Thereafter, the parcels at the pop-stations will be assigned to the crowd-workers and eventually reach the consumers.

When a worker accepts a task via a mobile app (similar to an Uber driver accepting a riding request), he/she can collect the parcel from the pop-station with a one-time-password. After that, the system notifies the consumer that the parcel has been taken, and starts tracking the real-time locations of the worker. When the parcel is safely delivered, a confirmation message is sent from the consumer and this transaction completes. To improve the system reliability and service quality, the identifies of crowd-workers have to be verified, which is common in apps like Uber and GrabTaxi.

We also note that UberRush[4] has provided parcel delivery service, using the drivers as workers. The major difference is that UberRush processes on-demand delivery requests and sends them to nearby drivers. It's one-time processing and there is no complex optimization issue. In contrast, we focus on the last-mile delivery to improve the efficiency of the whole supply chain. Our method is to leverage a large pool of crowd-workers to finish the last leg of delivery with any possible transportation means. In other words, we treat the transportation means as a black-box and these crowd-workers can walk, take a bus/train or drive a car to complete the delivery task.

When compared with conventional collaborative or synchronized approaches, as shown in Fig. 2, our system demonstrates the superiority from the following perspectives.

[4] https://rush.uber.com/how-it-works.