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Pocket-switch-network based services optimization in crowdsourced delivery systems☆

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ABSTRACT

There are two major issues in spatial crowdsourcing: travel route optimization and control policies. To address the two issues above, we introduce the concept of Pocket switch network (PSN) into the CD-system. First, we formulate a generalized optimization problem into three aspects of connectivity, profit and risk, motivated by the concepts in PSN. Afterward, these three aspects are mathematically described and optimized by a routing algorithm based on dynamic mobility and social graph. This algorithm consists of two parts: social graph extraction and social mobility based routing. Social graph learns the social knowledge of each patrician while social mobility based routing decides the leaving nodes of the passages according to their social graph. Finally, we evaluated the effectiveness and robustness of the proposed method on the realistic traces. The results demonstrated its superior performance in connectivity, profit, and risk.

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1. Introduction

The express service in cities is characterized by the heavy use of cars in urban areas [1–4]. It is thus important to propose some novel distribution method as a cleaner and more sustainable mode of transport [5], especially in the era of powerful cloud computing and storage [6,7]. A new distribution system, called crowdsourced delivery systems (CDS), is an application of spatial crowdsourcing [8] that uses the natural movements of local people to distribute physical packages from one location to another [3,9,10]. In detail, CDS considered the possibility of opportunistically using the pre-existing travel routines of a set of local participants by asking them to pick up a package from one exchange point and then drop it off at another exchange point. Fig. 1 illustrated the concept of CDS: one package is expected to reach the destination C4 from the origination A1. Three persons (A, B, C) participated in this delivery process. Each person follows different routines at different time points. By chaining together the mobility of several participants(A, B, C) we may cover a large area, possibly a whole country, without deploying more expensive and time-consuming infrastructure or making any extra journeys or using any extra fuel. In this case, we can ask individual A to bring the package to the place A4 and give it to individual B. Then, B has a chance to send it to C. Finally, C brings it to the destination.

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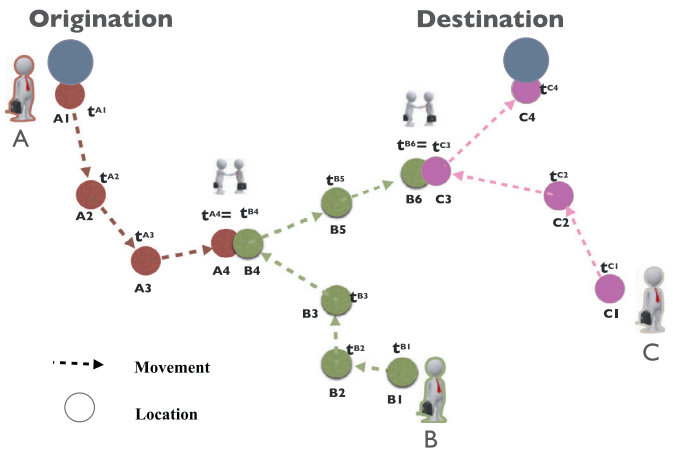

Fig. 1. Packages exchange example.

Basic crowdsourced delivery systems have already existed hiring strangers from the internet to deliver packages [5,11–13]. TwedExcan even tap into existing human journeys. The senders need to write the recipient's unique identifier on the package, such as their Twitter handle, while the TwedEx algorithm and the crowd do the rest [14]. To guarantee the connectivity in this network, some responders should be hired for urgent cases and some safe boxes could be set, from which the package is retrievable by a code. In theory, James et al. [5] gave a Markov decision process, which can describe what happens when an agent a person, a robot, or a piece of software performs an action without knowing exactly what its effect will be. Sadilek [15] tried to explore the power of employing local routing policies that could be executed in real time, relying only on simple statistics about future locations of people computed from historical data. The results show that packages can be delivered with remarkable speed and coverage. However, existing researches mainly focus on decreasing the delivery time, neglecting the profit and risk of the delivery process in practice. In this paper, we tries to take three aspects of connectivity, profit and risk into consideration in the CD systems and formulate them as the profit problem. There are two major issues in spatial crowdsourcing in real-world applications: travel route optimization and control policies. It is fundamental to optimize the travel route in developing an efficient crowdsourced delivery system (CD-system) that can distribute physical packages from one location to another. Control policies contribute more to the limit of exchange times and delivery time for one package or seeking a balance between profit, cost and quality of service.

To address the two issues above, firstly, we introduce the concept of Pocket Switch Network (PSN) into the CD-system. In detail, the message routing in PSN guides the nodes to decide whether to transmit their messages to the encounters. This kind of routing shows potential references to CD-system, especially in the delivery process. Thus the travel route optimization in the CD-system can refer to the message routing of PSN while the policies in the CD-system can refer to the message life-time management to solve cost and Qos problems. Secondly, we propose a CD-system research framework and model the travel route optimization problem in terms of control policies, introducing the concepts of lifetime, hops and routing protocols in PSN. Evaluate we utilize some methods for comparison.

In brief, the main contributions in this paper can be summarized as follows: (1) The concept of PSN in wireless network is introduced to the delivery problem in CD-system. Thus the package delivery problem can be modeled as a generalized optimization problem with considering three aspects (such as connectivity, profit and risk), organized by the CD-system research framework. This proposed framework supplies the theory support for the future application of CS-system. (2) A route optimization model is given to model the balance between kinds of control policies. The three aspects considered in the framework are mathematically described into integer linear programming for further optimization. (3) A social mobility-based routing is proposed based on human mobility patterns, making the delivery of packages efficiently. This routing connects human mobility to package delivery. Thus with well-studied human mobility prediction method, the routing of packages can be guided and optimized.

The organization of this paper is shown as follows. We introduce the concepts of PSN and CD-system in Section 2. Sections 3 and 4 introduce the policies model and the networking optimization separately. Experimental results based on real dataset are presented in Section 5 and, finally, Section 6 concludes this article.

2. The PSN and CD-system framework

2.1. Pocket switched network

In recent years, the Pocket switched network(PSN) [16,17] has emerged as a concept of concern in the research field of wireless delay-tolerant networks. This research tries to guide a network message from the source node to the destination node with the help of pedestrians. PSN, as a particular intermittent communication paradigm for mobile radio devices

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