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Fast participant recruitment algorithm for large-scale Vehicle-based Mobile Crowd Sensing

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ABSTRACT

Mobile crowd sensing has become an emerging computing and sensing paradigm that recruits ordinary participants to perform sensing tasks. With the highly dynamic mobility pattern and the abundance of on-board resources, vehicles have been increasingly recruited to participate large-scale crowd sensing applications such as urban sensing. However, existing participant recruitment algorithms take a long time in recruitment decision for large number of vehicular participants. In this paper, a fast algorithm for vehicle participant recruitment problem is proposed, which achieves linear-time complexity at the sacrifice of a slightly lower sensing quality. The participant recruitment problem is modeled as a unconstrained maximization problem without explicitly cost constraint and a trade-off parameter is introduced to control the recruiter cost. Trace-driven simulations on both real-world and synthetic data-sets are conducted to evaluate the performance of the proposed algorithm. Simulation results show that the proposed algorithm is 50 times faster than the state-of-art algorithm at the sacrifice of 5% lower sensing quality when the number of participants is over 1000.

1. Introduction

Crowd sensing is a rapidly developing computing and sensing paradigm [1]. Unlike conventional wireless sensor networks (WSNs), in crowd sensing systems, participants are recruited to collect and share sensing data using their own smart devices [2]. Substantial numbers of crowd sensing applications are designed to perform large-scale urban sensing tasks that are difficult for conventional WSNs, such as urban traffic monitoring [3,4], air quality report [5], urban noise monitoring [6], etc.

Vehicle-based Mobile Crowd Sensing (VMCS) is one of the most promising solutions in crowd sensing systems which recruits vehicles to serve as crowd sensing participants. VMCS is more powerful than ordinary crowd sensing systems. First, vehicles are equipped with more sensors, more powerful computing and communication resources, and they do not have strict energy constraints. Therefore, vehicles are more competent to perform sensing tasks than sensor nodes in WSNs or smart phones held by pedestrians in ordinary crowd sensing. Second, Vehicles have highly dynamic mobility to cover wider sensing area, which makes high quality crowd sensing with low budget possible because each recruited vehicle can

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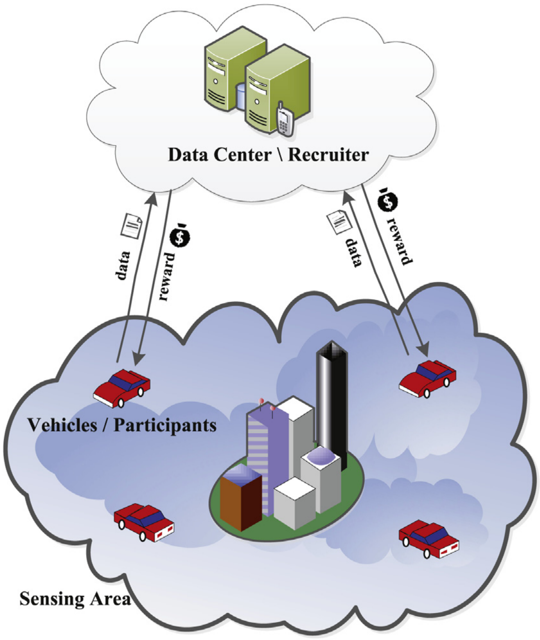

Fig. 1. Architecture of vehicle-based mobile crowd sensing systems.

move through multiple geographical regions [7]. Moreover, the mobility pattern of vehicles is highly predictable due to the prevalence of GPS-based car navigation systems. Taking advantage of predictable mobility pattern of vehicles, the sensing quality of crowd sensing systems can be significantly improved [8,7,2].

As shown in Fig. 1, a VMCS system is typically composed of two elements: sensing vehicles/participants and a data center/recruiter. Participants consist of drivers who are willing to collect and share sensing data by using either smartphones or OBUs (On Board Unit) in their vehicles. After completing crowd sensing tasks, participants will obtain either monetary or non-monetary reward from the recruiter [9]. The management of crowd sensing system is done by the data center, which also plays an important role as the recruiter. Because the recruiter is given with a limited budget, it can reward only a subset of participants. The *winner-pay auctions* approach is widely adopted in the participants recruitment procedure — recruiter chooses a subset of participants and rewards they to fulfill the crowd sensing tasks. Very recently, Luo et al. [10,11] proposed an incentive mechanism for crowdsourcing based on *all-pay auctions* approach that recruits all the participants but only reward a subset of good participants. However, the application of *all-pay auctions* approach may need some extra assistance because it still lacks a sense of security or reassurance [11]. Therefore, the selection of an optimal participants subset to balance between the crowd sensing quality and recruiter budget is still an important issue for the most *winner-pay auctions* based crowd sensing studies. Importantly, the recruitment decision must be made in a timely manner. On the one hand, unlike specially deployed sensor nodes, VMCS participants are voluntary drivers who will not waste too much time waiting for recruiter's decision. On the other hand, due to the highly dynamic mobility of vehicles, the trajectory information will be outdated if the recruiter spends too much time in participant selection.

Finding the optimal participants subset has been proved to be NP-hard, which means that there is no polynomial-time exact algorithm unless NP $=$ P. To circumvent the NP-hardness, researchers developed heuristic approaches to find near-optimal solutions. To the best of our knowledge, the computational complexity of existing participant recruitment algorithms is at least $\mathcal{O}(n^2)$ [7,12], where n is the number of participants. Such existing work will have a long recruiting time if there are a large number of participants. However, large-scale crowd sensing systems are designed to perform wide scale sensing tasks which require a large number of participants [13]. Therefore, a fast participant recruitment algorithm is necessary to make quick selection on large number of participants.

In this paper, we address the participant recruitment problem in large-scale VMCS systems. We first take advantage of the vehicular trajectory information to leverage the crowd sensing quality which is characterized by spatio-temporal coverage. In order to balance between the crowd sensing quality and recruiter cost, we formulate the problem as a unconstrained maximization problem without explicitly cost constraint. Instead, a trade-off parameter is introduced to control the recruiter cost. We prove that the formulated problem is NP-hard. To tackle the difficulty, we prove that the objective function is submodular. Then, taking advantage of the submodularity, we design a fast participant recruitment algorithm based on a linear time (1/2)-approximation method for unconstrained submodular maximization. Finally, we evaluate the proposed algorithm with trace-driven simulations on both real-world and synthetic data-sets. Specifically, the contributions of our work are summarized as follows: