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SACRM: Social Aware Crowdsourcing with Reputation Management in mobile sensing

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ABSTRACT

Mobile sensing has become a promising paradigm for mobile users to obtain information by task crowdsourcing. However, due to the social preferences of mobile users, the quality of sensing reports may be impacted by the underlying social attributes and selfishness of individuals. Therefore, it is crucial to consider the social impacts and trustworthiness of mobile users when selecting task participants in mobile sensing. In this paper, we propose a **S**ocial **A**ware **C**rowdsourcing with **R**eputation **M**anagement (SACRM) scheme to select the well-suited participants and allocate the task rewards in mobile sensing. Specifically, we consider the social attributes, task delay and reputation in crowdsourcing and propose a participant selection scheme to choose the well-suited participants for the sensing task under a fixed task budget. A report assessment and rewarding scheme is also introduced to measure the quality of the sensing reports and allocate the task rewards based the assessed report quality. In addition, we develop a reputation management scheme to evaluate the trustworthiness and cost performance ratio of mobile users for participant selection. Theoretical analysis and extensive simulations demonstrate that SACRM can efficiently improve the crowdsourcing utility and effectively stimulate the participants to improve the quality of their sensing reports.

1. Introduction

We have witnessed recently the dramatic proliferation of mobile computing devices such as smartphones and tablet computers [1]. Since these devices are generally equipped with a set of versatile sensors, mobile sensing (also known as participatory sensing or urban sensing) has emerged as a new horizon for ubiquitous sensing [2]. In a typical mobile sensing application [3,4], a data requester first publishes a sensing task to crowdsource, and then selects a number of mobile users interested in the task to collect the desired data. Once the participants finish the sensing task, they submit their sensing reports to the data requester and earn their task rewards. Such a new paradigm of information collection brings great benefits (e.g., efficiency and low cost) and also challenging issues by task crowdsourcing [5].

One of the challenging issues in mobile sensing is to select participants for crowdsourced sensing tasks. A few of research efforts have been invested to address the participant selection problem. Reddy et al. [6] develop a recruitment framework to select well-suited participants for sensing tasks based on the spatio-temporal availability and personal reputation. They highlight participant selection should highly depend on the location and time availability and trustworthiness of the participants. However, little attention has been paid to the underlying social attributes of mobile users (e.g. interests, living area), which are critical for task crowdsourcing [7–9], especially for participant selection. For a specific sensing task, it generally has a set of interested social attributes, and a large social attribute overlap between the task and mobile user indicates a potential matching and high task quality. For instance, if the published task is "*Find the cheapest Coca Cola in the Waterloo city*", the mobile users whose social attributes include "*Shopping*" and "*Waterloo*" might be preferred to be recruited in the task. While the published task changes to "*Find an unoccupied basketball court in the University of Toronto*", the mobile users whose social attributes include "*Sporting*" and "*Toronto*" should be preferred. Therefore, it is of great significance to consider the impact of social attributes on crowdsourcing, especially on the participant selection.

Another challenge in mobile sensing is to evaluate the trustworthiness of sensing reports and participants, and fairly allocate task rewards. In the presence of malicious participants, mobile crowdsensing is vulnerable to various types of attacks, e.g.,

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denial-of-service attack [10] and data pollution attack [11,3], etc. Reputation system is a promising technique and has been widely used in trustworthiness evaluation for mobile sensing [12,13]. Wang et al. [3] propose a reputation framework to evaluate the trustworthiness of sensing reports and participants. Huang et al. [11] employ the Gompertz function to compute the device reputation score and evaluate the trustworthiness of contributed data. However, most of the exiting works only focus on trustworthiness evaluation for participants, without adjusting their task rewards based on the quality of their sensing reports. Such that, the malicious users can still earn enough task rewards before their reputation goes to a low value. Therefore, in order to defend this attack and economically stimulate participants' contributions, it is crucial to adaptively allocate the task rewards to the participants according to their sensing report quality.

In this paper, we propose a **S**ocial **A**ware **C**rowdsourcing with **R**eputation **M**anagement (SACRM) scheme to select the well-suited participants and allocate task rewards in mobile sensing. Compared with the existing works, we synthetically consider the social attributes, task delay and personal reputation in mobile sensing and define a utility function to quantify the effect of the three factors on crowdsourcing. The major contributions of our work are four folds.

- We propose a participant selection scheme to choose the well-suited participants for sensing tasks and maximize the crowdsourcing utility under a fixed task budget. The proposed scheme consists of two participant selection algorithms, a dynamic programming algorithm to achieve the optimal solution and a fully polynomial time approximation algorithm to achieve the $(1-\epsilon)$-approximate solution.
- We propose a report assessment and rewarding scheme to measure the quality of sensing reports and allocate task rewards. Both of the report veracity and report delay are considered as two quality metrics for report assessment. And the task rewards are allocated according to the assessment results.
- We develop a reputation management scheme to evaluate the trustworthiness and cost performance ratio of mobile users for participant selection, which can stimulate participants to improve their report quality.
- We theoretically analyze the performance of the proposed participant selection algorithms. Extensive simulations demonstrate the effectiveness and efficiency of the SACRM scheme.

The remainder of the paper is organized as follows. Related works are reviewed in Section 2. In Section 3, we provide an overview of the system model and design goals. Section 4 presents the details of the proposed SACRM scheme. The theoretical analysis of SACRM is described in Section 5. We evaluate the performance of SACRM by extensive simulations in Section 6. Finally, Section 7 concludes the paper and introduces our future work.

2. Related work

As an emerging information collection mechanism, crowdsourcing has been extensively studied in mobile sensing. Most of the related works focus on studying the incentive mechanisms to stimulate the participation of mobile users for crowdsourcing [4,14–18].

Dynamic pricing is an effective incentive mechanism widely used in mobile sensing [4,14,15,19]. Yang et al. [4] propose two incentive mechanisms to stimulate mobile users' participation respectively for platform-centric and user-centric mobile sensing. For the platform-centric model, they present a Stackelberg game [20] based incentive mechanism to maximize the utility of the platform. For the user-centric model, they design an auction-based incentive mechanism that is proved to be computationally efficient, individually rational, profitable and truthful. Jaimes et al. [14] propose a recurrent reverse auction incentive mechanism using a greedy algorithm to select a representative subset of users according to their locations under a fixed budget. In [15], the authors develop and evaluate a reverse auction based dynamic pricing incentive mechanism to stimulate mobile users' participation and reduce the incentive cost. Besides the dynamic pricing mechanism, personal demand and social relationship are introduced into the incentive mechanism study [16,21,18]. Luo et al. [16] link the incentive to personal demand for consuming compelling services. Based on the demand principle, two incentive schemes, called Incentive with Demand Fairness (IDF) and Iterative Tank Filling (ITF), are proposed to maximize fairness and social welfare, respectively.

The majority of the existing incentive mechanisms are beneficial to stimulate the user participation, however, data assessment and reputation management are desired and critical to evaluate the trustworthiness of sensing data and mobile users [22–26,11]. Zhang et al. [22] propose a robust trajectory estimation strategy, called TrMCD, to alleviate the negative influence of abnormal crowdsourced user trajectories and identify the normal and abnormal users, as well as to mitigate the impact of the spatial unbalanced crowdsourced trajectories. Huang et al. [11] employ the Gompertz function [27] to compute the device reputation score and evaluate the trustworthiness of the contributed data. Since the reputation scores associated with the specific contributions can be used to identify the participants, privacy issues are highlighted in the reputation system design of mobile sensing [3,23,26]. Wang et al. [3] propose a privacy-preserving reputation framework to evaluate the trustiness of the sensing reports and the participants based on the blind signatures. Christin et al. [23] propose an anonymous reputation framework, called as IncogniSense, which generates periodic pseudonyms by blind signature and transfers reputation between these pseudonyms.

Recently, participant selection has been studied to achieve the optimal crowdsourcing utility [6,18]. Reddy et al. [6] develop a recruitment framework to enable the data requester to identify well-suited participants for the sensing task based on geographic and temporal availability as well as the participant reputation. The proposed recruitment system approximately maximizes the coverage over a specific area and time period under a limited campaign budget with a greedy algorithm. Amintoosi et al. [18] propose a recruitment framework for social participatory sensing to identify and select suitable and trustworthy participants in the friend circle, by leveraging the multihop friendship relations. However, they do not consider the social attributes of mobile users and adaptive rewards allocation, which play a significant role in crowdsourcing design.

3. System model and design goals

3.1. System model

We consider a typical mobile sensing system, which is applied in [3,4] and illustrated as Fig. 1. The system consists of a mobile sensing application *platform* and a large number of *mobile users*. The application platform generally resides in the cloud and consists of multiple sensing servers, and the mobile users connect to the platform through WiFi or cellular network. Each mobile user can publish his[1] sensing task on the platform, called as *data requester*. And the users who are finally assigned the sensing task are called

[1] No specific gender here, and the same applies in the following paper.