Computer Networks 102 (2016) 157–171

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

An incentive mechanism with privacy protection in mobile crowdsourcing systems☆

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ARTICLE INFO

Article history:
Received 16 January 2015
Revised 13 March 2016
Accepted 28 March 2016
Available online 1 April 2016

Keywords:
Crowdsourcing
Incentive mechanism
Privacy
Auction
Reputation

ABSTRACT

In order to improve the efficiency and utility of mobile crowdsourcing systems, this paper proposes an incentive mechanism with privacy protection in mobile crowdsourcing systems. Combining the advantages of offline incentive mechanisms and online incentive mechanisms, this paper proposes an incentive mechanism that selects the worker candidates statically, and then dynamically selects winners after bidding. The proposed incentive mechanism includes two algorithms which are an improved two-stage auction algorithm (ITA) and a truthful online reputation updating algorithm (TORU). Through simulations, we verify the efficiency and effectiveness of the proposed incentive mechanism, which can solve the free-riding problem and improve the efficiency and utility of mobile crowdsourcing systems effectively.

1. Introduction

The market of smartphones has proliferated rapidly in the recent years and continues to expand. Mobile crowdsourcing refers to crowdsourcing activities on smartphones or other mobile devices. Thanks to the improved, technological smartphone features, including reliable GPS, high resolution cameras, and continuously advanced software, mobile phone users can work on crowdsourcing tasks with ease [1,2]. Nowadays, these tasks involve more than simple site descriptions. Mobile crowdsourcing can be used to collect data either passively or actively. Users who have smartphones equipped with GPS can be located to create movement profiles [3,4]. In active crowdsourcing, smartphone users upload data including restaurant photos, accurate addresses and businesses (geocoding) or information about menus [5,6]. Meanwhile, mobile crowdsourcing can help with disaster rescue by coordinating rescuers in real time and documenting damage situations. Data gathered via mobile crowdsourcing is up-to-date and accurate, and a large amount of data can be delivered very quickly [7].

A mobile crowdsourcing system is a new form of commercial crowdsourcing system. In traditional commercial crowdsourcing systems, such as Amazon Mechanical Turk [8], an employer submits a task to the crowdsourcing platform and defines how much the workers will be paid per task and how the workers have to provide proof of a completed task. Random workers from the crowd choose to work on the task and submit the required proof to the crowdsourcing platform. The work proof is forwarded to the employer, who pays the worker if the task is completed successfully. However, in mobile crowdsourcing, it is common that workers are coming and bidding for a specific task sequentially, and the decision on accepting or denying a worker's bidding must be made by the platform instantly upon the user's arrival. Therefore, compared with the traditional commercial crowdsourcing systems, mobile crowdsourcing systems need higher real-time performance. In addition, in order to obtain better benefit and effectiveness, there is a bidding process for workers in mobile crowdsourcing systems.

Realizing the great potential of the mobile phone sensing, many researchers have developed numerous applications and systems, such as Sensorly [9] for making cellular/WiFi network coverage maps, VTrack [10] for providing traffic information. However, the existing mobile crowdsourcing systems face a serious practical

☆ Fully documented templates are available in the elsarticle package on CTAN.

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http://dx.doi.org/10.1016/j.comnet.2016.03.016
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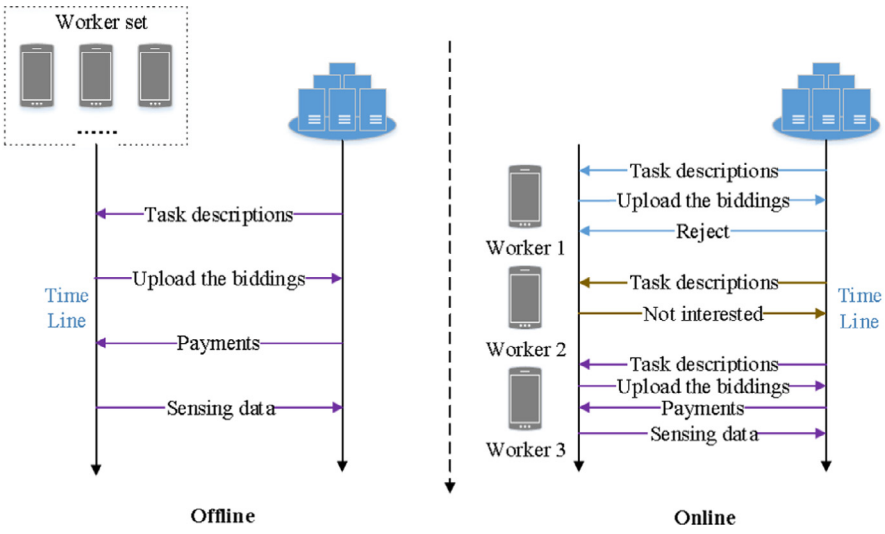

Fig. 1. Traditional offline settings and online settings for incentive mechanisms.

challenge: providing appropriate incentives for workers to participate and well-perform in tasks. More concretely, a requester needs to establish sufficient rewards to attract workers' contributions when workers do not solve tasks solely for altruistic motivations. For these reasons, designing an effective incentive mechanism to encourage workers' contributions is crucial to maintain the performance of crowdsourcing systems.

Therefore, how to maximize the social welfare is one of the most popular interests for mobile crowdsourcing systems. The establishment of incentive mechanisms becomes the focus in the research of optimizing mobile crowdsourcing systems. Traditional incentive mechanisms include two types which are offline settings and online settings. The mobile nature of these distributed computation and sensing powers further complicates the incentive mechanism design [11]. In a mobile crowdsoucing system, a task is described and posted by a requester together with the associated reward budget. If a worker is interested in a task, he will upload his bidding, *i.e.*, the solution (sensing time and sensing cost), to this requester [12]. According to this bidding, the requester can determine to accept this worker or reject this worker. The pioneer works mainly refer to the offline incentive mechanisms. The offline incentive mechanisms determine the winners in auction after all the participators upload their bidding [13]. These offline schemes assume that all the users present from the very beginning of one round of task distribution for bidding and cannot accept new bidding afterwards (shown in the left part of Fig. 1). In other words, the offline incentive mechanisms all fail in a more practical yet dynamic setting of mobile sensing. In order to resolve the problems of offline incentive mechanisms, Zhang et al. [14] proposed an online incentive mechanism, which is shown in the right part of Fig. 1. However, the online incentive mechanism fails to select the set of candidates from the workers' reputation database, resulting in inefficiency in the process of auction. Therefore, we combine offline settings and online settings to design incentive mechanism shown by Fig. 2. In the proposed incentive mechanism, the platform determines the worker set that can be assigned the given task based on the offline incentive mechanism; then once the selected workers arrive, there are transactions between platform and workers based on the online incentive mechanism. In addition, we add the privacy protection for the participant workers. Therefore, the proposed incentive mechanism can overcome the disadvantages of offline incentive mechanism and online incentive mechanism, protect workers' privacy, and improve the efficiency of mobile crowdsourcing system.

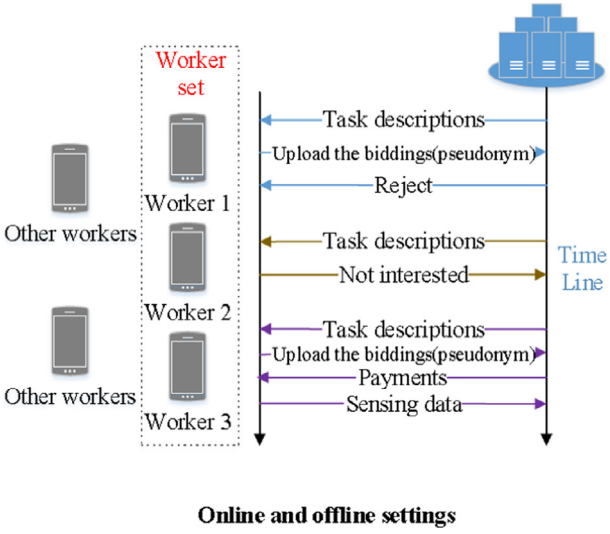

Fig. 2. The processing procedure for the proposed incentive mechanism.

In the process of an auction between workers and a platform, how to develop an auction algorithm is very important for improving the efficiency of mobile crowdsourcing systems [15]. In addition, there exists a lot of free-riding phenomena in complex networks such as social networks, computer networks and so on. Unfortunately, networks cannot automatically adjust the selections of nodes for trust strategies. The individuals in a network have the nature of selfishness, thus an individual prefers to select the strategies that can increase its benefit. The free-riders prefer to select a unreliable strategy as their first choice, resulting in the decrease of network benefit [16].

Therefore, how to establish an effective incentive mechanism to inspire the selection of reliable strategies is very important for complex networks. Mobile crowdsourcing systems are developed upon mobile social networks, and they are full of complexities, thus mobile crowdsourcing systems have the features of complex networks. Such features include a heavy tail in the degree distribution, a high clustering coefficient, assortativity or disassortativity among vertices, community structure, and hierarchical structure. Therefore, for mobile crowdsourcing systems, the establishment of an incentive mechanism is also an important research focus.