User Rewarding and Distributed Payment Platforms for Mobile Crowdsensing Systems

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ABSTRACT

Mobile Crowdsensing (MCS) has become in the last years one of the most prominent paradigms for urban sensing. In MCS systems, citizens actively participate in the sensing process by contributing data from their mobile devices. To make effective a MCS campaign, large participation is fundamental. Users sustain costs to contribute data and they may be reluctant in joining the sensing process. Hence, it is essential to incentivize participants. Several incentive mechanisms have been investigated, such as monetary rewarding. In this context, distributed payment platforms based on custom built blockchains assume a fundamental role. We aim to develop a platform to distribute micro-payments following rewarding schemes. The key idea is to differentiate between users through several parameters, such as the amount of acquired data and the Quality of Information (QoI), according to the particular campaign and the need of the organizers.

1 INTRODUCTION

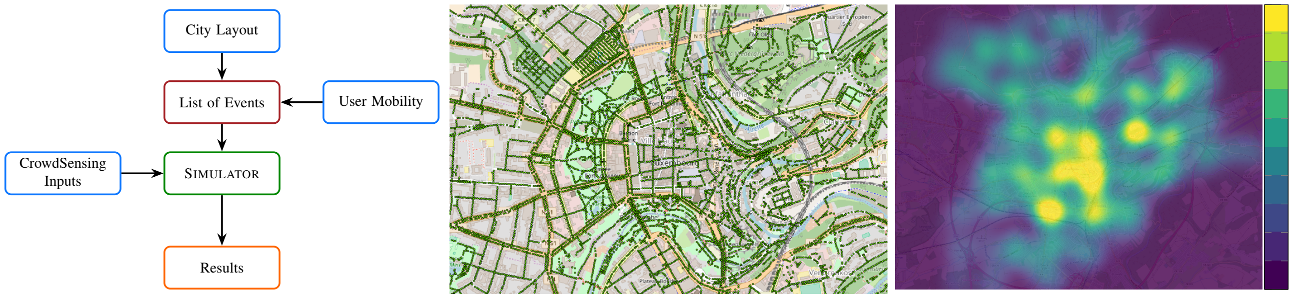
Nowadays, the unprecedented growth of population living in urban areas calls for a sustainable urban development. To this end, sensing is fundamental to monitor the current status of infrastructures and the resource utilization [1]. Deploying sensing infrastructures is typically expensive, while including citizens in the loop through mobile crowdsensing (MCS) has been proven as a win-win strategy [2]. Indeed, it allows to exploit already deployed infrastructures with no need of further investments. Mobility and intelligence of human participants guarantee higher coverage and better context awareness, if compared to traditional sensor networks. In addition, users ensure self-maintenance and recharge of the devices that act as sensor and communication mobile nodes, unprecedentely from other paradigms. Smartphones are equipped with a rich set of sensors suitable in multiple domains, such as environmental monitoring, health care, public safety and intelligent transportation systems. Available communication technologies deliver the acquired data to a collector, typically located in the cloud, for data processing and analysis.

MCS follows a Sensing as a Service (S^2aaS) business model, which makes data collected from sensors available to cloud users. IoT and MCS are key enablers in the S^2aaS models, whose efficiency is defined in terms of the revenues obtained through data selling and the costs. The success of crowdsensing campaigns relies on large participation of citizens, who sustain costs to contribute data (e.g., the battery drain of their devices or monthly data plans for cellular data connectivity). Hence, it is fundamental to devise efficient data collection frameworks (DCFs) and to reward users for their contribution. Consequently, the organizer of a sensing campaign (e.g., a government agency, an academic institution or a business corporation) sustains costs to recruit and compensate users for their involvement [3].

Several incentive mechanisms, e.g., social or monetary, have been and are currently under investigation. Many researchers are challenging the issues to design practical data collection schemes for MCS data markets [4]. Our aim is to exploit distributed payment platforms that run applications on custom built blockchains to provide incentives in MCS campaigns, according to rewarding schemes. The motivation is twofold. First, these platforms enable organizers to design custom user rewarding schemes that could differentiate between contributions according the need of the application, taking into account several parameters (e.g., quantity and quality of contributed data). Second, they provide the possibility to move funds without the need of a central authority or counterparty risk.

2 BACKGROUND ON OUR PREVIOUS WORKS

Devising energy efficient DCFs is crucial to foster citizens' participation. To this end, in the early-stage of our work we investigated the costs users sustain for sensing and reporting operations and we proposed a distributed energy efficient DCF [5]. It aims to minimize the battery drain for sensing and reporting, while maximizing the utility of data collection and, as a result, the quality of contributed information. Then, we proposed a methodology to investigate the performance of several DCFs and compare them from an energy perspective, but also considering amount of collected data and fairness among participants. To this end, we developed a custom Android application for smartphones that can implement different data reporting mechanisms and we performed energy and network-related measurements with a power monitor and Wireshark. As MCS systems require large participation to be effective, performing experiments on real testbeds is not often feasible. To this end, simulations are a valid alternative and CrowdSenSim [6] is a custom simulator we specifically designed to assess the performance of crowdsensing activities in large urban areas. CrowdSenSim supports pedestrian mobility in citywide scenarios and is composed by independent modules representing inputs of the particular MCS campaign (see Fig. 1(a)). Modeling the urban environment with high precision is a key ingredient to obtain effective results and CrowdSenSim provides the street network graph at any desired level of precision (see Fig. 1(b)) through an algorithm running on its background. All the individual walking paths are obtained before simulation runtime to ensure the scalability of the platform. During runtime, users move following their predetermined trajectories and contribute data according to the implemented DCF, exploiting sensors typically available in mobile devices. The simulator computes the amount of gathered data for each user and the associated battery drain for sensing and reporting. After the runtime it is possible



(a) Main modules of CrowdSenSim **(b) The green dots are lanes where users can walk** **(c) Normalized distribution of contributed data**

Figure 1: CrowdSenSim modules, walking paths and possible results

to obtain different results, such as heatmaps with the normalized amount of gathered data (see Fig. 1(c)).

3 DISTRIBUTED PAYMENTS FOR MOBILE CROWDSENSING

The organizers of crowdsensing campaigns (e.g., a company, a municipality, or an academic institution) have no longer the need to acquire an infrastructure to perform a campaign, but exploit already deployed ones in a pay-as-you-go basis. Many researchers are investigating on several incentive mechanisms, mainly monetary ones because they result more effective than others in fostering citizens' participation. In this Section we will analyze user rewarding and decentralized payment platforms that enable developers at running smart contracts on custom built blockchains.

3.1 User rewarding

The success of a MCS campaign relies on large participation of citizens and on their willingness to contribute data. To this end, rewarding users is essential. Fig. 2 shows the process of user recruitment, selection and rewarding in a typical crowdsensing campaign. First, the organizer of the campaign needs to recruit participants from citizens. Then, a central authority allocates tasks to the recruited users and selects contributors amongst the group according to policies specifically designed from the organizer. In other words, the user selection consists in choosing participants who are more suitable for given reasons to accomplish sensing tasks. Selection is totally dependent on context-awareness and can be based on different strategies, such as spatial or temporal sensing coverage, energy costs or technologies needed for delivering data. Finally, selected users contribute data to the central collector, which rewards them according to some criteria that depend on the sensing campaign design, such as amount of collected data and quality of information. Research works based on monetary incentives usually focus on finding an optimal task policy under a limited budget by considering that each task has different requirements. Leveraging the vast adoption in crowd applications of multiple sensors, current rewarding strategies are suboptimal as fail to differentiate between active versus non-active user involvement, type and quality of reported data. Our aim is to exploit several criteria to develop a user rewarding scheme based on a strong differentiation between participants who contribute in different ways, compensating the most active ones.

3.2 Decentralized platforms to distribute payment

Rewarding users implies the need to distribute micro-payments to them according to the criteria of each sensing campaign. Deliver micro-payments through participants requires distributed and reliable platforms, which could run smart contracts to respect the designed rewarding schemes between the parties. A smart contract is a self-executing digital contract verified through peers, without the need of a central authority. In this context, blockchain technology is fundamental by providing a transparent, unalterable, ordered ledger and by enabling a decentralized and secure environment. Hyperledger[1] is an open-source project to develop and improve blockchain frameworks and platforms. It is based on the idea that only collaborative software development can guarantee the interoperability and transparency to adopt blockchain tecnologies in the commercial mainstream. Ethereum[2] is a decentralized platform that allows developers to distribute payments on the basis of previously chosen instructions without a counterpart risk or the need of a middle authority. Developers have the opportunity to run applications with their rewarding rules on a custom built blockchain with a shared global infrastructure to distribute payments. Exploiting these platforms could allow the organizer of a sensing campaign to decide how to reward citizens according to several parameter previously decided on application-basis (e.g., amount of data, type of sensor, QoI, time of reporting).

3.3 Application for rewarding citizens

Existing distributed payment platforms allow to run custom applications to move funds in accordance with instructions, representing a perfect match with rewarding schemes for crowdsensing systems. The key idea is to distribute payments differentiating between citizens that actively perform tasks and report highly accurate data and others that passively perform data reporting, often resulting in low-quality contributions. To this end, payment platforms running smart contracts could reward users according to chosen criteria, which vary on different campaigns' requirements. We aim

[1]https://www.hyperledger.org/

[2]https://www.ethereum.org/

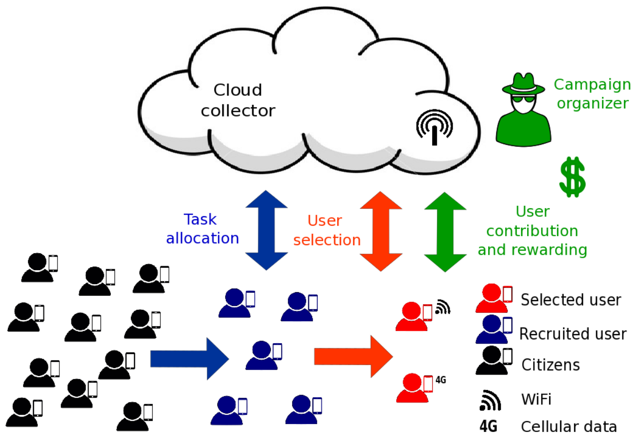


Figure 2: User selection and rewarding in MCS systems

to develop a custom application that runs on a blockchain-based distributed payment platform, investigating how to design a rewarding scheme that could differentiate between users according to their contribution. First, rewarding strategies should consider quality and quantity of contributed information. Then, a sustainable scheme should also consider to award in a better way a user who has a lower level of battery or will contribute for a higher energy consuming task. Finally, available communication technologies should be considered because typically WiFi entails lower costs than cellular data connectivity (e.g., a user could pay for a monthly data plan). In other words, active citizens sending a large amount of data with a high QoI and low level of remaining battery should be rewarded better than passive ones with full battery and sending low-quality data.

4 RELATED WORKS

Incentives for MCS frameworks are typically either monetary or social. The latter include research works that focus on citizens who express their availability to be recruited for contributing information during a MCS campaign and establishing social interactions. To give a few examples, Xiao et al. [7] analyze the task assignment problem in mobile social networks and propose a scenario in which users send tasks to others who accomplish the task, in order to minimize the average makespan. Chessa et al. [8] investigate mobility and interaction patterns between volunteers to increase performance of MCS campaigns, exploiting existing social ties and introducing community-based tasks to share social relationships. The former are research works that investigate how to efficiently allocate tasks under a limited budget and how to foster user participation with monetary rewarding in order to achieve the goals of the sensing campaign. Zheng et al. [9] investigate the business paradigm of data trading designing a data collection scheme for crowdsensed data markets. They propose a framework called VENUS, which aims to maximize the profit and minimize the payment. Xu et al. [10] propose a distributed active learning framework that aims to minimize prediction errors under a limited amount of budget, focusing on trade-offs between inference performance and costs of data acquisition. Chen et al. [11] present a payment scheme which aims to maximize profit and to select qualified contributors. To the best of our knowledge, currently there are no works that exploit existing distributed payment platforms running smart contract based on rewarding schemes to foster user participation in MCS systems. The closest work to our idea is [12], where the authors investigate incentives and preservation of privacy and propose a dual-anonymous reward distribution scheme to achieve reward-sharing incentive and privacy protection for both customers and contributing users. This mechanism allows a campaign organizer to motivate user contribution by claiming electronic coins from a bank, while protecting the identities of both sides.

5 CONCLUSION

Active citizen participation in MCS campaigns is becoming a common practice. Devising efficient DCFs and having a large participation of users is essential for the success of a campaign. In our early-stage work, we first proposed an energy efficient DCF which minimizes the costs user sustain, while maximizing the utility of collected information. Then, we developed an Android application that can implement DCFs and we profiled real energy and network measurements exploiting a power monitor and Wireshark. Then, these results have been included in the CrowdSenSim simulator, specifically designed to assess the performance in real urban environments. Next step of our work is to exploit existing rewarding platforms based on custom built blockchains that run smart contracts and develop on it a custom application to differentiate payments between users that actively send high-quality data and passive low-quality contributors.

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