Future Generation Computer Systems 86 (2018) 222–233

Contents lists available at ScienceDirect

Future Generation Computer Systems

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

Beaconing Control strategy based on Game Theory in mobile crowdsensing

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HIGHLIGHTS

- We propose a low cost sensing data uploading scheme.
- We propose a beaconing control strategy based on Game Theory in mobile crowdsensing.
- We conduct extensive simulations based on the random-waypoint mobility pattern and two widely-used real-world traces.

ARTICLE INFO

Article history:
Received 7 September 2017
Received in revised form 19 February 2018
Accepted 6 April 2018

Keywords:
Mobile crowdsensing
Beaconing Control
Game Theory
Delivery ratio
Energy consumption

ABSTRACT

Mobile crowdsensing is a new paradigm in which a group of mobile users exploit their smart devices to cooperatively perform a large-scale sensing job over urban environments. According to the different price plans, all the users could be segmented into following two groups: Pay as you go (PAYG) and Pay monthly (PAYM). Taking the uploading cost into consideration, a PAYG user prefers to upload the sensing data through a PAYM user, rather than uploading it by itself. In order to utilize the limited energy to deliver the sensing data to the PAYM users, each user should decide a suitable switch between high beaconing frequency and low beaconing frequency. In this paper, we propose a Beaconing Control strategy based on the Game Theory in mobile crowdsensing (BCGT), where each user decides the beaconing frequency according to its payoffs between sensing data delivery ratio and energy consumption. Then, each user's life cycle is divided into three phases: high beaconing phase, game theory phase, and low beaconing phase, in order to efficiently utilize the limited energy. We conduct extensive simulations based on random-waypoint mobility pattern and two widely-used real-world traces: *roma/taxi* and *epfl*. The results show that compared with other beaconing control strategies, BCGT achieves a higher delivery ratio with an identical initial energy.

1. Introduction

Recently, a lot of smartphones have been used in people's daily life, and a variety of sensors (e.g., camera, sound sensor, and position sensor) have also been equipped on the smartphones, which make the mobile devices more powerful than that in the last few years. Thanks to this, a new sensing paradigm called *mobile crowdsensing* is proposed [1] to recruit a group of mobile users who can jointly perform a large-scale sensing task through their smartphones.

By now, the research work in terms of mobile crowdsensing [2] mainly include: platform design [3–6], user recruitment strategies [7–9], and incentive mechanisms [10–14]. Among them, the main concern for most mobile crowdsensing applications is the cost for uploading the sensing data, the cost influences the willingness to participate in a crowdsensing activity. Compared with uploading the sensing data costly via 3G or 4G, a user prefers to upload the sensing data through a free way. In this paper, we first use a low-cost and privacy-protected sensing data uploading scheme, to separate the users into two groups [15] according to following ways: if a user's uploading cost is decided by the amount of data, then it will be put into the Pay As You Go (PAYG) user group; while if a user's uploading cost is fixed for a month-long period, then it will be put into the Pay monthly (PAYM) user group.

Consider that, a PAYG user with sensing data attempts to upload the sensing data. Obviously, the PAYG user prefers to upload through a PAYM user freely, rather than uploading it costly via 3G or 4G. Therefore, the problem changes to calculate the encounter probability between the PAYG user with sensing data and any other PAYM user. An easy solution is to obtain the information (location, name, historical trace et al.) of the PAYM users, which easily causes the privacy leakage problem. The propagation scheme proposed in

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https://doi.org/10.1016/j.future.2018.04.013
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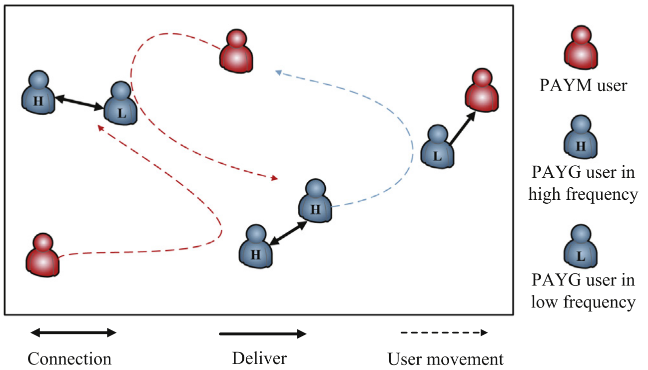

Fig. 1. Beaconing control strategy for mobile crowdsensing: the sensing data taken by PAYG users needs to be uploaded before the deadline. If a user stays in high beaconing frequency, it will communicate with the others in a high probability, while the energy is consumed quickly. So, in order to utilize the limited energy to deliver the sensing data to the PAYM users, a PAYG user with sensing data should decide the switch between high beaconing frequency and low beaconing frequency.

this paper tries to spread the sensing data as widely as possible in the flooding copy manner, rather than revealing the privacy information of the PAYM users.

However, during the sensing data propagation, the beaconing could consume energy rapidly and shorten its battery life significantly [16], especially in Mobile Crowdsensing where the users' energy cannot be supplied in a timely manner. Therefore, energy conservation and communication efficiency are both important in the sensing data propagation. There must be a trade-off between the energy consumption and the sensing data dissemination. The longer the phone is in high beaconing frequency, the faster the energy is consumed. However, a higher beaconing frequency will also lead to a better communication probability, which assists in sensing data dissemination. On the contrary, the longer the phone is in low beaconing frequency, the slower the energy is consumed. However, a lower beaconing frequency will also lead to a worse communication situation, which misses many connection probabilities. Therefore, it is really important to decide a suitable switch frequency between high beaconing and low beaconing. The different energy cost between high beaconing frequency and low beaconing frequency gives rise to the following dilemma; should a user be in a high frequency in order to increase their encounter probability, i.e. the probability of establishing a connection, or should they stay in a low frequency that saves energy?

In this paper, we propose a Beaconing Control strategy based on the Game Theory in mobile crowdsensing (BCGT), where each user controls its beaconing frequency through the trade-off between sensing data delivery ratio and energy consumption. The life cycle is divided into the following three phases: high beaconing frequency, beaconing frequency in Game Theory, and low beaconing frequency. As shown in Fig. 1, when a PAYG user's energy is sufficient, it stays in a high beaconing frequency. Along with the consumption of energy, a user could control the beaconing frequency in Game Theory, which means it uses a probabilistic method to stay in a high frequency. When the energy is urgent, the user will stay in a low beaconing frequency. Through the above beaconing control strategy, a user could utilize the limited energy to achieve a satisfactory sensing data delivery ratio.

The main contributions of this paper are briefly summarized as follows:

- We propose a Beaconing Control strategy based on Game Theory in mobile crowdsensing (BCGT), where each user controls its beaconing frequency through the trade-off between the sensing data delivery ratio and energy consumption.

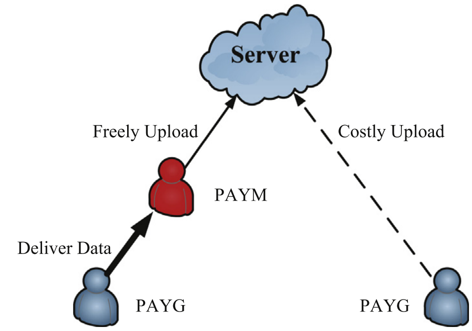

Fig. 2. Different ways to upload the sensing data for a PAYG user.

- In order to maximize the delivery ratio within the limited initial energy, we divide each user's life cycle into the following three phases: the high beaconing phase, Game Theory phase and low beaconing phase.
- We conduct extensive simulations based on the random-waypoint mobility pattern and two widely-used real-world traces: *roma/taxi* and *epfl*. The results show that, compared with other beaconing control strategies, BCGT achieves a higher delivery ratio with an identical initial energy.

The remainder of this paper is organized as follows: The network model and problem formulation are presented in Section 2. Section 3 analyzes the beaconing problem in mobile crowdsensing. The beaconing control strategies (Game Theory and Autonomic Scheme) are proposed in Section 4. In Section 5, we evaluate the performance of the proposed beaconing control strategies through extensive simulations. We review the related work in Section 6. We conclude the paper in Section 7.

2. System model and problem formulation

2.1. Network model

The network environment in this paper is composed of a crowd of mobile users, denoted by the set: $N = \{n_1, n_2, \ldots, n_n\}$. The users could be divided into two groups according to their price plans: Pay as you go (N_G) and Pay monthly (N_M). The different kinds of uploading actions are shown in Fig. 2.

Two users could communicate with each other only when they are in contact with each other, meanwhile they could detect each other. Each user has an identical communication radius, and two users are in contact when they enter the communication ranges of each other. Beaconing could be used to detect each other, and each user has a limited initial energy, which will be consumed by beaconing action. Each user's device has the following two modes: regular mode (high beaconing frequency) and energy-saving mode (low beaconing frequency). They could make a decision between the above two modes, according to the current conditions (remainder energy, network parameter, et al.). The main notations are illustrated in Table 1.

2.2. Problem formulation

We focus on the research in terms of the beaconing control problem for mobile crowdsensing. Without loss of generality, the sensing task has an uploaded deadline T_d which means that the sensing data must be uploaded before time $t + T_d$. The PAYG users with the sensing data could do one of the following two uploading actions before deadline (Fig. 2): (1) deliver the sensing data to a PAYM user and upload freely or (2) upload the sensing data by