Collaborative Localization in Participatory Sensing with Load Balancing

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***Abstract*—The increasingly popular smartphones enable participatory sensing systems to collect location-based sensing data for different tasks. However, GPS positioning is very energy consuming, which could drain a mobile device's battery quickly. High energy consumption may threaten the participants and reduce the sustainability of the participatory sensing systems. In this paper, we propose a collaborative localization strategy with load balancing. Simulations with real traces showed that our proposed solution can save more than 80% of the energy consumption for localization in the entire network with load balancing.**

I. Introduction

The key idea of participatory sensing is to have ordinary citizens collecting and sharing sensor data from their surroundings using their smart devices, such as iPad, smartphone, and Google Glass, etc. Many mobile applications require continuous location information of users to provide real-time and relevant services. GPS localization is a commonly used technique nowadays. However, GPS is very energy consuming, which can drain the battery in 5-6 hours. Compared with GPS, localization using cellular network is more energy-efficient, but its accuracy (around hundred meter) is less than GPS, which is not high enough in many location-based applications.

Our research is motivated by the application scenario shown in Fig.1. The figure shows a population of mobile users collaboratively collecting location-related sensing data for a certain task. Some mobile devices serve as data collectors, which turn on the required sensors periodically and hand over the collected sensing data to aggregators via short range wireless communication, such as WiFi or Bluetooth. Other devices serve as data aggregators, which gather the sensing data from the data collectors and upload the data to the remote server through cellular networks. To prevent that some aggregators may drain out of battery more quickly than other aggregators, we select the data aggregators based on their remaining batteries to support load balancing.

II. Related work

Participatory sensing was first proposed in [1], and then followed by many proposals. For example, Dutta et al. [2] has developed a participatory sensing system which allows participants to measure their personal exposure to air pollution, and Kanjo [3] has showed a system which allows participants to collect and share the noise pollution information.

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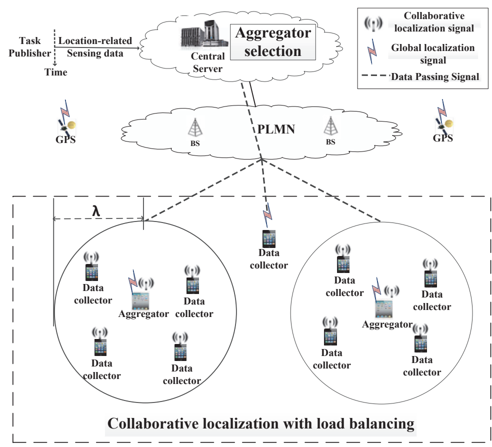

Fig. 1. System overview

Energy saving is of significant importance in participatory system. Some approaches suggested to reduce the sampling [4]. Other approaches utilized additional sensors such as accelerometers and orientation sensors to assist localization [5]. Our approach aims at minimizing the energy consumption through collaborative localization without deploying any beacons nodes and supports load balancing at the same time.

III. System Model and Problem Formulation

We consider performing participatory sensing in a region as shown in Fig. 1. It comprises of a central server and a set of M smartphones users moving in the region. Among the M participants, some are selected as data aggregators, while the remaining participants work as data collectors. Each data collector collects sensing data periodically and forwards the collected data to its nearest aggregator through short-range wireless communication, e.g. WiFi. The data aggregators also collect sensing data periodically. In addition, they gather the sensing data uploaded by their surrounding collectors, label the data with location and upload the labeled data to the central server.

Our main task is to find an optimal aggregator allocation with load balancing so that the energy consumption of the entire network is minimized. We formulate it as the Aggregator Allocation Selection problem (AASP).

IV. The Proposed Solution

We have proved that AASP is an NP-hard problem, thus we propose a Greedy based Aggregator Selection (GAS) algorithm to solve the problem. We also propose an improved Simulated Annealing (SA) based Aggregator Selection (SAAS) algorithm. SA is a generic probabilistic metaheuristic for global optimization problem. It can locate a good approximation to the global optimum of a given function in a large search space.

V. Performance Evaluation

We evaluate the performance of the proposed collaborative strategy using the (Microsoft Research Asia) GeoLife dataset. The GeoLife project has collected the trajectories of volunteers (ordinary citizens) in Beijing for three consecutive years. Each trajectory is marked by a sequence of time-stamped GPS points that contain the users location (latitude, longitude and altitude) at different time. We store all the trajectories in a geographical MySQL database and select a region with high movement density for our simulation.

First, we study the energy consumption without load balancing. Fig. 2 compares the energy consumption of our solutions with the traditional approach. We vary the number of participants by selecting a subset of participants randomly in the dataset. In the traditional approach, all mobile participants turn on their GPS for localization . We find that our approach can save up to 88% of the energy compared with the traditional approach. We also see that the SAAS algorithm saves more energy than the GAS, since it is able to reach the global optimal solution.

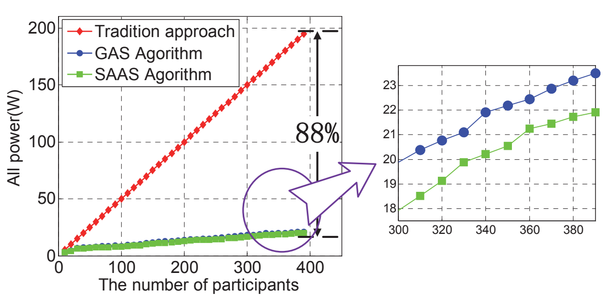

Fig. 2. Comparison with traditional GPS approach

We further study how the load balancing relaxation parameter ε impact on energy consumption. Fig. 3 shows ε's impact on energy consumption. The 'Lower Bound' in the figure refers to the energy consumption without load balancing. It minimize the total energy consumption in the network, which can save 88% of the energy compared with the traditional approach. From Fig. 3, we can save 81% of the energy compared with traditional approach when $\varepsilon = 0$.

When $\varepsilon = 10$, we can save 87% of the energy compared with traditional approach, which is pretty close to the 'Lower Bound'. ε bounds the maximum and minimum number of associated data collectors per aggregator compared with the mean value. The results indicate that there is a tradeoff between total energy consumption and load balancing.

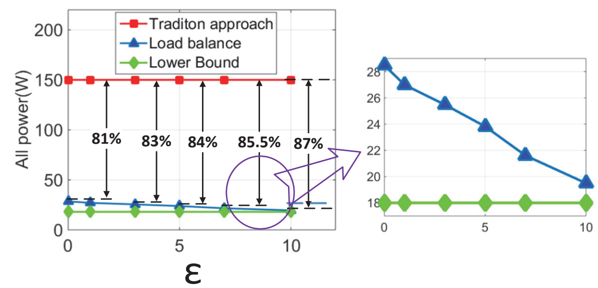

Fig. 3. ε's impact on energy consumption

VI. Conclusions and Future Work

In this paper, we presented a collaborative localization strategy to improve the sustainability of participatory sensing system by reducing the energy consumption of the mobile devices. We formulated an Aggregator Allocation Selection Problem (AASP) and proposed two novel algorithms to minimize the energy consumption of the entire network by performing collaborative localization between the data aggregators and the data collectors. We evaluated the performance of our proposed SAAS algorithm and GAS algorithm through extensive simulations based on real mobility traces. The results showed that our proposed localization strategy can provide load balancing and save more than 80% of the total energy in the network.

Acknowledgment

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