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Distributed Localization for Participatory Sensing Systems

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Abstract

The focus of this paper is on participatory sensing in which every participant carrying smartphone senses its environment and shares it with server. Most of the applications require location information to perform sensing activity. But, GPS drains considerable amount of energy if used for localization. There exists a centralized localization approach to detect a set of devices for the role of broadcaster which must turn on GPS. Its neighbouring devices rely on them to calculate their position. In this paper, we provide a novel distributed solution for finding roles for the participating mobile devices. It is important in real scenario to alleviate server from the burden of assigning roles. Our proposed approach does not make any assumption about the presence of infrastructure or device capabilities, other than the availability of WiFi and the ability to know devices within the WiFi range. To the best of our knowledge, this is the first protocol for distributed localization in participatory sensing system. Simulation results using real dataset demonstrate that our algorithm is capable of assigning role in 70-85% less time compared to the centralized algorithm but consumes 12-15% more energy as it does not find the optimal set of broadcasters which requires global information.

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1. Introduction

In this paper, we focus on participatory sensing in which participants actively participate in sensing activity and collaborate to accomplish a given task[3]. Participatory sensing supports various applications ranging from health services to environment monitoring, most of which are dependent on location information. For accurate location information, devices depend on GPS which is a major source of power depletion in cell phones. There exists a novel scheme called device-to-device[7] localization which relieves some devices from using GPS and thereby saves the phone's energy. Energy consumption and accurate real time positioning is quite crucial for the sensing task. Localization takes into account mobility and relative positioning of devices. Some devices need to turn on GPS for accuracy and others depend on them for calculation of their location. Wang et al.[2] propose a framework, providing an energy model and greedy method for collaborative localization. They find an optimal set of broadcasters which can minimize energy of the system. The algorithm iterates over the entire set of participants to find the one which can minimize the most system energy and allocates it the role of the broadcaster. The process continues until no device can be chosen for the role of broadcaster so that energy can be minimized. However, it is a centralized approach which

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requires the server to allocate role to the participating devices. Motivated by the applications of participatory sensing and the need of distributed algorithm for dynamic users, we aim to propose a time efficient distributed algorithm. We have also considered the residual energy of smartphones for deciding role of the participants.

The rest of the paper is organized as follows. Section 2 presents related work. Section 3 provides an overview of the system under consideration. In Section 4, we present the energy consumption model. In Section 5, we describe our distributed protocol followed by a comparison between the distributed and the centralized approach. The experimental results are presented in Section 6. Conclusion follows in Section 7. In the paper, we have used participants, devices, nodes and smartphones interchangeably.

2. Related Work

Participatory sensing has shown its great potential in numerous application domains such as health care, environment monitoring, transportation, social networks, safety, industrial monitoring and maintenance, academia and government agencies. For example, in NoiseSpy [14], application deploys mobile phones for monitoring environmental noise by logging sound levels. Similarly, CommonSense [13] is an application developed to monitor air quality using hand held devices. Most sensing techniques which need position information rely on GPS. However, it drains sufficient power of the phones. Hence, many alternatives to GPS have been proposed compromising accuracy of the devices. Shafer et al. [12], presented an indoor WLAN-localization method using accelerometer. This is an energy efficient technique but can work only in indoor environment. Many localization techniques are based on Bluetooth technology [10 11]. Other methods for localization require fixed or mobile beacons to estimate position [8 9]. Song et al. [7], propose a device-to-device localization method which uses propagation model of wireless signals. The movements of devices are calculated by inertial sensors using step-up method and change in distance between devices are modelled by change in signal strength. This method was deployed by Wang [2] for collaborative outdoor localization. A server selects set of devices which must turn on GPS while neighbouring devices rely on them for calculating location using device-to-device localization. A sorting based algorithm has been proposed recently [1] to find optimal set of broadcasters. However, we investigate a distributed protocol for this framework.

3. System Overview

We consider a participatory sensing system framework as proposed by Wang [2]. It consists of server (sink), task publisher and set of smartphone users in the region. The task publisher sends the sensing task to server. In the role assignment phase, all participants decide their role and in localization period they find their location and collect sensing data. There can be three type of roles [2] - broadcaster (aggregators), location information receivers (LIRs), normal participants (NP). Only broadcasters and normal participants send back data to the server which processes them to accomplish the given task. We are considering that users sense environment irrespective of the task and the server can process the aggregated information as per the requirement. However, it can be considered that sensing is performed based on task in which case the server will have to send the task information to broadcasters and normal participants which shares it with the LIRs. We assume that all users are mobile. This corresponds to the realistic case. All nodes are equipped with GPS, accelerometer and other sensors which are of use. Nodes are also equipped with WiFi and cellular network but are only used when needed; rest of the time, they are turned off. No assumption is made about homogeneity of node dispersion, network density, or distribution of energy.

4. Energy Consumption Model

We consider that nodes periodically execute distributed algorithm to reassign their role. Let this interval be $[t_1, t_2]$. If t_x is the time taken for role assignment then $[t_1 + t_x, t_2]$ is time taken for the localization. We use same notations that are used in [2] to denote power of GPS (e_g), cellular network (e_c), WiFi sending (e_{w1}) and receiving (e_{w2}), energy of broadcaster (e_b), LIR (e_l), NP (e_n) and system. Fig. 1, Fig. 2 and Fig. 3 show energy consumption at different intervals for broadcaster, LIR and normal participants respectively during $[t_1, t_2]$. Nodes keep WiFi on until role assignment to know their neighbours. So, they use $e_{w1} + e_{w2}$ during $[t_1, t_1 + t_x]$ irrespective of whether they become broadcaster,