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Towards On Demand Road Condition Monitoring Using Mobile Phone Sensing as a Service

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Abstract

With the increased need for mobility and the overcrowding of cities, the area of Intelligent Transportation aims at improving the efficiency, safety, and productivity of transportation systems by relying on communication and sensing technologies. One of the main challenges faced in Intelligent Transportation Systems (ITS) pertains to the real time collection of traffic and road related data, in a cost effective, efficient, and scalable manner. The current approaches still suffer from problems related to the energy consumption of mobile devices and overhead in terms of communications and processing. We have previously proposed the concept of Mobile Sensing as a Service (MSaaS), in which mobile owners can offer the sensing capabilities of their phones as services to other users. This ability to offer sensory data to consumers on demand can bring significant benefits to ITS and can constitute an efficient and flexible solution to the problem of real-time traffic/road data collection. In this paper, we adapt the concept of MSaaS to the area of transportation, and present an on-demand vehicular sensing framework. This framework enables a data consumer to send a sensing trigger request to a vehicular sensing platform, which matches it with the most suitable set of data collectors that would perform the sensing task, and return the data to the platform for validation and processing. The collected data is then used to infer intelligence about the city and send the required traffic information to the data consumer, in a timely manner. The proposed model and architecture were validated using a combination of prototyping and traffic simulation traces, and the obtained results are very promising.

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Keywords: Sensing as a service; Intelligent transportation systems; traffic estimation; road condition monitoring

1. Introduction

With the rapid widespread of smartphones that come embedded with a variety of sensors (e.g. gyroscope, GPS, and accelerometer), users now hold in the palms of their hands powerful devices that can be used as personal sensing

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platforms enabling the collection of a wealth of contextual information. This integration of sensing technology in mobile devices opens the door for a new sensing approach and era – the mobile phone sensing[1] era. Mobile devices can act as super sensors that are readily deployed and can be used to dynamically collect intelligence about cities. There are two main mobile phone sensing paradigms: Participatory sensing in which the user actively participates in the data collection and sensing activity; and opportunistic sensing that occurs in a transparent automated manner without any user involvement[1].

Sensing technologies constitute one of the key enablers of Intelligent Transportation Systems (ITS). In fact, ITS rely on communication and sensory technologies along with data processing and analysis techniques to improve the safety, efficiency, and productivity of transportation systems[2]. Typical ITS applications include traffic management, road safety applications, and route planning applications. The collection of real time traffic and road conditions constitutes an important challenge in such applications. Conventional methods for the collection of such information typically relied on infrastructure sensors such as surveillance cameras and inductive loops, which may not be always available and involve high deployment and maintenance costs[3]. Recently, the idea of using mobile crowdsensing for the collection of traffic and road related information has attracted attention in academic and industrial forums. In this approach, regular users equipped with sensor-enabled phones collaborate to sense data related to phenomena of interest (e.g. traffic conditions and accidents' occurrence)[4]. The reliance on the drivers carrying sensor-embedded phones for the collection of traffic related information brings important benefits. The first benefit pertains to the easy on-demand deployment of a large-scale network of sensors, since millions of mobile phones are carried everyday by vehicle drivers. Moreover, this approach leads to important time saving and costs reduction with respect to traditionally deployed specialized sensing infrastructures. Examples of mobile crowdsensing systems used in the area of intelligent transportations include MIT's CarTel[5] and Microsoft Research's Nericell[6]. These systems mainly adopt a continuous sensing approach in which data is continuously sampled from all cars on all street segments (without the explicit involvement of users), and then processed offline on the backend server. This imposes high energy-requirements on mobile devices, entails significant overhead on the mobile communication infrastructure, and results in large amounts of data requiring processing on the server. Furthermore, the opportunistic automated data collection strategy adopted by such systems gives rise to privacy concerns by mobile users, which may not wish to share sensory data that reveals sensitive information about themselves (e.g. their geographic location).

We have previously proposed the concept of Mobile Sensing as a Service (MSaaS) as well as a business model enabling its realization[7]. In this concept, we perceive mobile devices as data collectors and mobile device users as willingly participating in the sensing process and offering their phones' sensory data collection capabilities as services to other users. In this work, we adpat the concept of MSaaS into the area of transportation and propose a vehicular sensing framework enabling on-demand road condition monitoring in efficient and flexible manner. In the proposed model, traffic related data sensing about any region of interest would occur on demand, when triggered by a sensing request. The set of targeted users acting as data collectors will be determined by the sensing platform based on their presence in the region of interest, phones' sensing capabilities, and availability to participate in the sensing activity. Furthermore, the data collector has the possibility to accept or reject the sensing request. The elaborated approach provides reduced energy consumption and communication overhead between the mobile phones and the server since only the required data will be sent to the sever when needed, and the ability of users to control sensing activities thus having control on the sharing of their personal information.

The rest of the paper is organized as follows: In Section II, we present some illustrative scenarios. Section III discusses the related work. Section IV details the proposed vehicular sensing framework. This is followed by the system validation and experimental results in Section IV. We end the paper with our conclusions.

2. Vehicular Sensing Illustrative Scenarios

Many interesting scenarios could be enabled by the concept of on-demand sensing as a service. In the sequel, we provide two participatory and opportunistic transportation related scenarios:

- ***On-Demand Accident Scene Intelligence Gathering:*** When an accident occurs, it takes the police some time to arrive to the accident site. In order to collect information about the accident before arrival to the site, the police force could send an on-demand sensing request that would be conveyed by the sensing platform to a select group