Participatory Sensing: Crowdsourcing Data from Mobile Smartphones in Urban Spaces

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Abstract. The recent wave of sensor-rich, Internet-enabled, smart mobile devices such as the Apple iPhone has opened the door for a novel paradigm for monitoring the urban landscape known as participatory sensing. Using this paradigm, ordinary citizens can collect multi-modal data streams from the surrounding environment using their mobile devices and share the same using existing communication infrastructure (e.g., 3G service or WiFi access points). The data contributed from multiple participants can be combined to build a spatiotemporal view of the phenomenon of interest and also to extract important community statistics. Given the ubiquity of mobile phones and the high density of people in metropolitan areas, participatory sensing can achieve an unprecedented level of coverage in both space and time for observing events of interest in urban spaces. Several exciting participatory sensing applications have emerged in recent years. For example, GPS traces uploaded by drivers and passengers can be used to generate realtime traffic statistics. Similarly, street-level audio samples collected by pedestrians can be aggregated to create a citywide noise map. In this talk, we will provide a comprehensive overview of this new and exciting paradigm and outline the major research challenges.

Keywords: Participatory Sensing, Mobile Crowdsourcing, Urban Sensing.

1 Introduction

In recent times, mobile phones have been riding the wave of Moore's Law with rapid improvements in processing power, embedded sensors, storage capacities and network data rates. The mobile phones of today have evolved from merely being phones to full-fledged computing, sensing and communication devices. It is thus hardly surprising that over 5 billion people globally have access to mobile phones. These advances in mobile phone technology coupled with their ubiquity have paved the wave for an exciting new paradigm for accomplishing large-scale sensing, known in literature as *participatory sensing* [1], [2]. The key idea behind participatory sensing is to empower ordinary citizens to collect and share sensed data from their surrounding environments using their mobile phones.

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Mobile phones, though not built specifically for sensing, can in fact readily function as sophisticated sensors. The camera on mobile phones can be used as video and image sensors. The microphone on the mobile phone, when it is not used for voice conversations, can double up as an acoustic sensor. The embedded GPS receivers on the phone can provide location information. Other embedded sensors such as gyroscopes, accelerometers and proximity sensors can collectively be used to estimate useful contextual information (e.g., is the user walking or traveling on a bicycle). Further, additional sensors can be easily interfaced with the phone via Bluetooth or wired connections, e.g., air pollution or biometric sensors.

Participatory sensing offers a number of advantages over traditional sensor networks which entails deploying a large number of static wireless sensor devices, particularly in urban areas. First, since participatory sensing leverages existing sensing (mobile phones) and communication (cellular or WiFi) infrastructure, the deployment costs are virtually zero. Second, the inherent mobility of the phone carriers provides unprecedented spatiotemporal coverage and also makes it possible to observe unpredictable events (which may be excluded by static deployments). Third, using mobile phones as sensors intrinsically affords economies of scale. Fourth, the widespread availability of software development tools for mobile phone platforms and established distribution channels in the form of App stores makes application development and deployment relatively easy. Finally, by including people in the sensing loop, it is now possible to design applications that can dramatically improve the day-to-day lives of individuals and communities.

A typical participatory sensing application operates in a centralized fashion, i.e., the sensor data collected by the phones of volunteers are reported (using wireless data communications) to a central server for processing. The sensing tasks on the phones can be triggered manually, automatically or based on the current context. On the server, the data are analyzed and made available in various forms, such as graphical representations or maps showing the sensing results at individual and/or community scale. Simultaneously, the results may be displayed locally on the carriers' mobile phones or accessed by the larger public through web-portals depending on the application needs.

In this talk we will provide a comprehensive overview of this exciting and new paradigm. Section 2 will provide an overview of innovative participatory sensing applications that have been proposed in literature. Section 3 will provide a detailed discussion on the key research challenges posed by participatory sensing and focus on novel approaches to deal with the same. Finally, Section 4 will conclude the article.

2 Innovative Participatory Sensing Applications

The emergence of the participatory sensing paradigm has resulted in a broad range of novel sensing applications, which can be categorized as either *people-centric* or *environment-centric* sensing. People-centric applications mainly focus