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Managing Mobile-based Participatory Sensing Communities

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Abstract

Participation of mobile phone users in sensorial data collection both from the individual and from the surrounding environment presents a wide range of opportunities for truly pervasive applications. This paper highlights relevant issues related to mobile-phone participatory sensing and describes an architecture framework to flexibly create new communities of data interest, to manage and interact with those communities and to finally provide useful information to the users.

1 Introduction

The large number of mobile phones renders the device as the most distributed and pervasive instrument in the world. In addition to providing basic voice services, mobile phones can provide insightful information regarding the community we live in with exceptional granularity and coverage. For example, the technology for determining the geographic location of cell phones and other hand-held devices is becoming increasingly available. In the Mobile landscape project [3], location information from mobiles has been utilized to provide detailed maps of the density of people in different cities, such as Graz [1], at different times of the day or to identify the most visited archeological sites in Rome [2]. The maps represent a powerful tool to urban planners, transport authorities and traffic engineers. Systems like the Mobile Landscape can be extensively improved if communities of mobile users, namely *publishers*, authorize the transmission of sensed data collected autonomously from their devices. Collected data would provide a much richer set of information that can be analyzed in order to send back relevant data to the community of users, namely *subscribers*.

Mobile phone-based Participatory Sensing (MPPS) systems involve a community of users sending personal information and participating in autonomous sensing through their mobile phones. Sensed data can be obtained from sensing devices present on mobiles such as audio, video and motion sensors, the latter available in high-end mobile phones. Sensed data can also be obtained from external sensing devices that can communicate wirelessly to the phone (for example through Bluetooth). Most of the current data collection and data delivery architectures, such as the ones used in the projects in [3] and [4], are based on

geo-centric web interfaces such as Google Maps. It would be appealing to provide a system that can deliver distilled information on-demand directly to mobile phone users. For example, one can imagine a system that can alert a subscriber through an sms if he is in the vicinity of a district that presents a high level of carbon dioxide in real time. In this example, information is firstly collected from mobile users that have a carbon dioxide sensor provided on their mobile and are currently in the area. Secondly, the data is processed and delivered to the user subscriber. In this paper we enhance the existing systems and investigate how to manage and render the data collected available to interested user communities directly on their mobiles. In our system, which aims to be linked to the existing participatory sensing databases, users can publish information and subscribe to particular data directly with their mobile phones therefore increasing greatly the flexibility of the participatory sensing system.

The remainder of the paper is organized as follows: firstly we define the entities involved in a MPPS system and then we highlight some relevant issues to be considered when deploying an MPPS system. Subsequently, we introduce a flexible management architecture to allow creation and maintenance of information exchange among communities of participatory sensing users to flexibly build and interface with new participatory sensing communities.

2 Entities of a MPPS system

As depicted in figure 1, an MPPS system consists of participatory mobile users connected to one or more participatory sensing Servers (PSSs) through one of the communication standards described in section 3. Participatory mobile users can be grouped in participatory communities of publishers (CPubs) and participatory communities of subscribers (CSubs) according to the data they provide and request respectively. CPubs and CSubs are completely decoupled in the sense that users can join/leave multiple communities independently. Users can also join different CPubs and CSubs according to the information they want to obtain and the sensed data that they can provide. PSSs, as interconnected distributed servers, represent the core of the participatory system. They collect information from CSubs, then classify and index sensed data according to attributes. At this point data are only recognized through attributes and are completely independent the initial CPubs.

PSSs share and examine sensed data to finally distribute distilled information to CSubs.

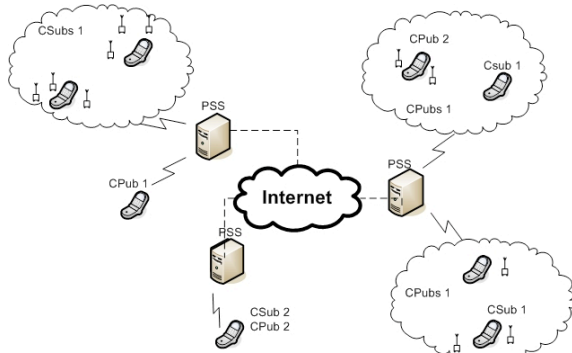


Figure 1. Mobile Phone Participatory Sensing (MPPS) systems consist of mobile phones, sensor devices connected to a mobile and Participatory Sensing Server

3 Issues in Participatory Sensing

The deployment of participatory sensing systems raises a number of issues:

Privacy and security The user should trust the MPPS management architecture which should in turn ensure that the data sharing is controlled and that the privacy of the publishers is respected. On the other side, a subscriber should be protected against malicious entities that can compromise the information by MPPS.

User Participation Users are generally interested in participating at a particular CPub only if the user can obtain benefits for himself or possibly understand the benefits for a wider community. Methods for participation that promote user interest should be identified.

Power consumption MPPS systems should assure the user of a low sensing and data transmission rate to avoid early battery depletion of the mobile. Power consumption issues also need investigation.

Data management and usability A management entity, which mainly reside at the PSS, is responsible for filtering and interpreting data arriving from the publishers. The distilled information will then be sent back to the subscriber as described in section 4.

Choice of transmission standard At present, mobile phones can autonomously embed and transmit sensed data through (1) Short Message Service (SMS) or Multimedia Message Service (MMS); (2) SMTP protocol used for emails; (3) Packet switching for access to the internet or (4) Short automatic phone calls. The choice of the standard should be based on aspects such as service cost, network scalability, expected data traffic to be routed to the nearest PSS and power consumption of the publisher device.

In participatory sensing, technical, commercial, and privacy/participation are closely related issues. On the technical side, we need to identify the appropriate sensors to

put into mobile phones and the hardware integration methods for providing these sensors with minimal power overhead and maximum usability. These technical considerations give rise to business and commercial issues relating to MPPS, such as why would the mobile phone manufacturer put sensors into mobile phones? Manufacturers will place sensors into mobile if they see an economic benefit, mainly that the enhanced mobile phones can enable value-added services so that the user is willing to pay more for a mobile phone with sensors. Determining what these value-added services are is another commercial issue of interest to cellular providers, and it will significantly influence the provider's support for MPPS systems. The final consideration relates to privacy/participation: why will the user accept to share information from their phones? The MPPS business model should gain the users' trust and provide them with incentives for using the system. For example users can get free sms messages or free calling during off-peak hours if they agree to participate in an MPPS system. The above discussion clearly indicates that it is important to adopt a holistic view that addresses the technical, commercial, and user acceptance issues for building a successful participatory sensing system.

4 The management architecture

MPPS systems should be supported by a management architecture that offers network scalability, loose coupling between users, flexible data collection/distribution and tolerance to network changes as users might join or leave the MPPS system at any time. The Publish/Subscribe messaging paradigm offers an intuitive option to manage MPPS systems. We envision a system where publishers post messages to an intermediary mediator entity, which is located at the PSS, that performs some services like data filtering and interpreting. The distilled data are then broadcasted to interested users. The management architecture can use the Partisan base layer described in [5].

The MPPS management architecture will build on top of Partisan providing methods for the end user to interface with the MPPS system. A CPubs is identified by a set of attributes, the most important are: Sensed Interests, Publisher features, Location, Duration, community ID, Subscriber restrictions, etc. In fact, although communities are managed locally and independently, a PSS can share sensed data globally with others PSSs. Attributes are used by other MPPS management architectures to collaborate and share information in line with provided restrictions. The attributes also help identifying the CPubs uniquely around the globe. In this way, it is possible to have an inclusive view of the sensed data available. We now describe the management architecture network phases for new community of subscribers.

The **CSub initialization phase** consists of:

New CSub Application in which a user can request to initiate a new CSub by filling mandatory fields provided;

New CSub Verification in which the MPPS management verifies a) the correctness of the application and b) whether the data requested is already in a particular

PSS. In case of approval the new CSub is indexed so to be visible on the mobile phones of other PSSs;

New CSub Advertisement If the CSub application is approved, then the home PSS advertises the new community in the participatory sensing database that is available to the users. If the CSub application is rejected, then the PSS discards this request. By selecting a particular CSub, a user can observe important parameters such as publisher benefits, sensing community objectives, privacy, other restrictions etc.

The **CSub maintenance phase** consists of:

Data collection phase where sensed information from publishers are collected and stored in a local database. Attributes of public sensed values will be also available to other communities.

Data synthesis phase in which data are filtered and interpreted so to obtain useful information for the subscribers;

Data distribution phase where the collected data are transmitted to the CSub subscribers.

Finally the **CSub Termination Phase** is activated by natural expiration of a CSub or forced by the PSS mediator.

5 Conclusion

This paper has highlighted relevant issues related to participatory sensing. Secondly, we introduced a management system based on the publish and subscribe mechanism, which aims to be linked to the existing participatory sensing databases, to handle distributed mobile phone-based participatory sensing systems. The management layer, which builds on top of the Partisan architecture, provides flexible methods to create, maintain and interface publishers and subscribers of sensed data for participatory sensing communities. This work enhances the existing participatory systems by considering the next steps related to managing and rendering the participatory data collected available to interested user communities directly on their mobiles. This would personalize and improve the flexibility of participatory sensing systems that are currently delivering information only through geo-centric web interfaces.

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