Providing User Self-Contained Location Information Using Mobile Phones

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Abstract. This paper describes our work to enable user location acquisition using existing telecom network infrastructures (cellular base stations). Different from many others, this solution does not require the involvement of a telecom provider; instead, it allows the users to customize how their location information will be derived and shared. A number of issues have been addressed related to building a self-contained location database, and an example application is presented to demonstrate the use of this solution in a pervasive computing scenario.

1 Introduction

Location information is probably the most important context information used in pervasive computing, where various location-based services have been demonstrated as typical example applications. Global Positioning System (GPS) technology has been commonly used to provide mobile users with different kind map-based services. However, due to the sensitivity for obstructions in the signal path to the satellites, it does not work effectively indoors. To overcome this problem, many other attempts have been tried in the field: besides the explicit user interactions such as swiping a card or pressing a button [1], researchers have demonstrated various infrastructure-based location sensing systems using different technologies, such as infrared [2], ultrasound [3] and RFID [4] etc. One common drawback with these solutions is their high cost for building the system infrastructure. Another drawback is that they allow tracking of the user in the system, which imposes a potential threat towards user's privacy.

With the increasing concerns of protecting user privacy in pervasive computing environment, client side positioning using stationary beacons for location sensing has been proposed as a plausible way. As a recent example, PlaceLab [5] has used Wi-Fi access points as location beacons. However, it requires pervasive presence of Wi-Fi access points, which may not always be possible. Combining the concerns from different aspects, including privacy protection, energy consumption, accuracy scale, as well as the form factor and user's economic affordance, providing user with pervasive location sensing is still an open issue in the area.

Tom Pfeifer et al. (Eds.): Advances in Pervasive Computing 2006
Adjunct Proceedings of Pervasive 2006, Dublin, 7-10 May
books@OCG.at Vol. 207, ISBN 3-85403-207-2

2 Location Detection Using Cellular Base Stations

Compared with Wi-Fi and other location sensing systems, today's telecom networks (cellular base stations) already have a pervasive coverage, and are serving a vast amount of users. This technology has the potential to provide mobile phone users with location detection capability based on information regarding nearby base stations. Some telecom service providers already offer commercial services of this kind, like the *Find Friends* [6] provided by AT&T in U.S., and *Friend Finder* [7] by TeliaSonera in Sweden. These services allow a user's friends to gain an awareness of her current location by simply sending and receiving Short Message Service (SMS) messages. To protect the user's location privacy, each person has to be authorized by the user beforehand in order to get access to the user's location information. The user can also choose to terminate a buddy's location access at any time. The Find Friends service will further notify the user each time her location is queried by others.

These services provide a simple means for a user to share her current location with other people. There are however a number of remaining issues that should be dealt with. In addition to the cost and the burdensome actions of sending and reading multiple SMS messages, the user is very limited with respect to how location information is represented and shared. Firstly, the location information is derived by the commercial service, which may not allow users to define places in the person's own terms, such as "home", "office" etc. Secondly, it is not possible to define access policies towards different requestors: e.g., my location can only be seen by colleagues during my working hours (9:00–17:00, Monday to Friday), while family access is granted all the time; and neither do these services support presenting user location in different granularity towards different requesters, e.g., presenting location in city scale to strangers but in street scale to close friends and family members. Thirdly, these services are generally restricted to a specific operator's network, something that heavily restricts the ways in which the location information could be used. Being dependent on a third party service provider means that the service could be changed at any time or even be removed, like the AT&T Find Friend service. Finally, the potential threat to the user's location privacy still remains, similarly to other infrastructure-based location sensing solutions.

To overcome theses problems, we developed a user *self-contained* location sensing system based on cellular network base stations. By term user self-contained, we mean two main characteristics which are different from the above-mentioned commercial services: 1) The location detection is executed on user's cell phone without the involvement of any other third parties including the network and service providers; therefore, it provides better user privacy protection. 2) Various customizations are supported for a user to define personalized location derivation and sharing.

3 Realizing the Self-Contained Location Sensing

In our design, the location sensing process runs on user's mobile phone, where it continuously checks the Cell-ID of the base station that the phone is currently using. Then the process tries to map this Cell-ID with places that have earlier been defined

by the user. These predefined place definitions which we refer to as *Spots,* consist of two parts: 1) a set of labels with semantic information, such as "Home", or "Stockholm Central Station" and 2) a profile that defines the spot (in this case a Cell-ID). The application on the phone can either look up the place definitions in a local database or it can do a lookup with a remote service over a GPRS/UMTS connection. This communication link is also used to publish the user's location so that it can be used by other applications.

It is hard to extract absolute location information from Cell-IDs since the telecom providers normally do not give out the position of their base stations. A key feature of the application is therefore the ability for the users themselves to define new places as a combination of the current Cell-ID and some semantic information describing the place. Due to the wide coverage of each base station (about a circle of some hundred meters radius), one base station could however cover multiple places a user would want to define. We also discovered that at some places, a mobile phone may periodically switch between different base stations due to factors such as proximity to the coverage boundary and density of base stations in the area. Therefore, a many-to-many mapping between places and their associated base stations is used in the location database.

To further increase the versatility of our Cell-ID based location sensing, GPS coordinates can be used in two ways: 1) GPS coordinates can be attached to places in the location database. 2) The signal coverage of each base station can be mapped to an area (e.g., a circle) using a set of GPS coordinates. Introducing the GPS coordinates into the database makes it easier to interface with applications that uses coordinates to represent locations, such as different kind of map-based applications.

4 Example Application

To demonstrate the use of our location sensing solution, we have connected it to a Personal Communication Service (PCS). This service can receive and respond to text messages from different Instant Messaging (IM) networks on behalf of a user. In addition, it also publishes the user's presence information (including her current location) to these networks. As shown in Figure 1, user *beichuang's* symbolic location "at home" (together with a timestamp) is seen by his buddy (beichuang2000) through different channels (YIM, MSN and Skype accounts).

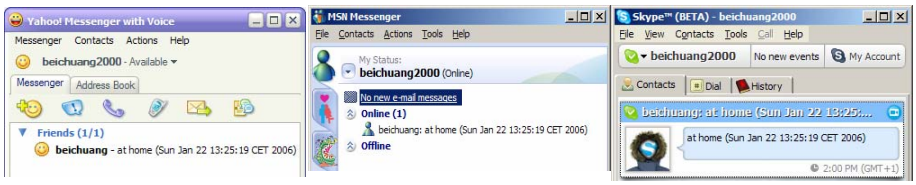
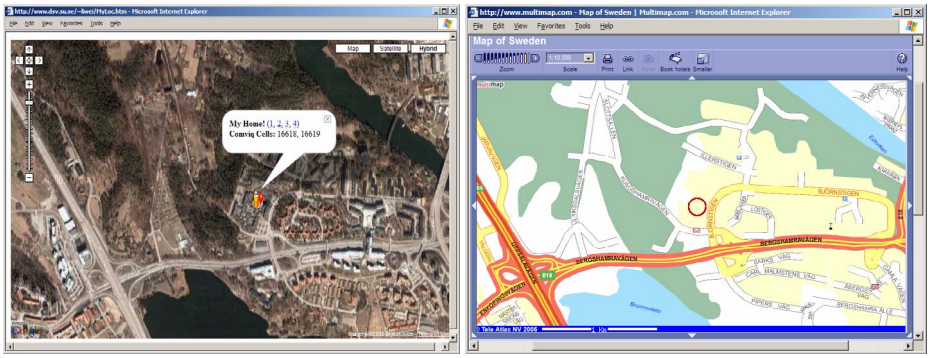


Fig. 1. PCS extends ordinary IM presence with symbolic location

The location sensing application runs on the user's mobile phone (SonyEricsson P800), reporting the detected Cell-ID and its radio signal strength to her PCS over a GSM/GPRS connection. In addition to converting the Cell-ID into a symbolic

location, and presenting it to different IM networks, the authorized buddies may also receive a URL showing the user's location in different maps (like in Figure 2).



(a) Google Satellite Map **(b) Map with Multimap.com**
Text: *"My Home! (extra 4 map links) Comviq Cells: 16618, 16619"*
Fig. 2. PCS displays user location with online maps

5 Related Work and Future Plan

PlaceLab[5], CellSpotting [8] and very recently, the MobiLife [9] project also provide support for GSM Cell-ID detection in a way similar to our solution. They however all require access to GPS coordinates to define a place. Our work instead uses semantic representations of places relieving the user from the dependence of GPS-devices.

Our upcoming work will focus on providing support for sharing place definitions among users. We would also like to investigate the granularity "real users" would use when revealing their location depending on who is asking for the information.

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