Privacy Concerns for Indoor Location-Based Services

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INTRODUCTION

Systems that provide location-based services (LBSs) register all available services in a central entity, so users may subscribe to this entity and thus be able to obtain certain services according to their geographic location. Geographic location information—known as geolocation information—may be known through different mechanisms in manual or automatic ways. Most of these mechanisms imply the use of radiofrequency technologies, through the use of devices such as GPSs, mobile telephones, and others, typically using triangulation techniques to determine the position of the device (and the user carrying it). Most of these systems are implemented for users moving outdoors. Also, geolocation information is under the control of the entity that manages the user's subscription, which motivates concerns regarding how this information is used.

LBS systems require servers where geolocation information is stored, and where objects, attributes, and relations are described in different layers or abstraction levels. This geolocation information enables the representation and visualization of maps, political divisions, roads, electrical networks, buildings, lakes, and so forth. This information is thus stored statically and superposed on a geographical zone, forming a complex map with attributes that can be used to perform queries. These systems commonly use a pull-based paradigm, where users make explicit requests to the server, which responds with geolocation information and related services. For instance, a car driver could request information regarding the closest restaurants, shopping centers, and so on. This example also shows another general characteristic of LBS systems: most of the services are static in nature, meaning that usually the services are in the same place and it is the user who actually moves.

Advances in LBS systems and mobile computing technologies have caught the attention of telephone companies, which seek to provide competitive services to their users and differentiate themselves from their competitors.

Being able to locate artifacts and persons can raise privacy concerns. In fact, these privacy concerns represent one of the most important barriers for the adoption of systems providing location-based services. Thus, effective mechanisms for addressing these privacy concerns should be implemented.

LOCAL MOBILITY

Some of the so-called "knowledge workers" present a high degree of mobility in their daily activities (Belloti & Bly, 1996). Local mobility refers to dynamic patterns of mobility that take place close to the worker's office, or even within a building, when a worker is carrying out her duties, collaborating with colleagues, and so forth. A clear example of this is the kind of work performed in a hospital, as it involves a high degree of mobility of patients, equipment, resources, and personnel within the hospital facilities. Doctors and nurses frequently move in order to carry out their activities; likewise, hospital personnel transport information and equipment through different areas.

Recent studies (Rodríguez & Favela, 2003; Muñoz, Rodriguez, Favela, Gonzalez, & Martinez-Garcia, 2003; Santana et al., 2005) have aided to characterize hospital work in order to design and evaluate different technologies to support processes in that type of environment. As a result, several requirements and needs have been identified for the development of systems that take into account contextual parameters, such as location. Therefore, these needs and requirements also apply for the design and development of LBS systems in hospitals. Among the requirements for information and services identified, related to the location parameter, are:

- **Location of Artifacts:** In many cases, when doctors or nurses finish using medical artifacts, they do not pay attention to returning them to their original place. As a result, when other persons (or even themselves) need these artifacts, they have to invest some time trying to locate them. Checking the availability of some equipment is also a concern.
- **Location of Persons:** During work shifts, medical personnel require locating a specialist to consult on some particular case, or even to get aid in an emergency.

In this context, the concept of artifacts refers to medical equipment, document, furniture, electronic devices, and any other physical object (static or mobile) that hospital personnel use to carry out or support an activity.

LOCATION OF ARTIFACTS AND PERSONS

In order to provide location-based service discovery, it is first necessary to have some mechanisms to estimate the location of artifacts and persons through some device. Usually, location of devices is basically categorized as device-centered and network-centered. The first one allows the device, through some mechanism, to estimate its own position; that is, it is only the device and no other that can estimate and know its physical location. Meanwhile, network-based mechanisms require that a different entity within the network perform the estimation of a device's physical location; this way, when a device wants to know its location, it has to consult the entity in the network that is in charge of determining it. Some good examples of device-centered systems are RADAR (Bahl & Padmanabhan, 2000), Cricket (Priyantha, Chakraborty, & Balakrishnan, 2000), and AeroScout. In this type of system, a PDA, mobile phone, or some other type of mobile device usually performs the estimation. So, in some way the estimation is person centered, as persons normally carry the devices, but only if the device is fully in control of the calculations for determining the current position; and if the device is turned off for some reason, the location cannot be determined. Some examples of network-centered systems are Active Badge (Want, Hopper, Falcao, & Gibbons, 1992), Ubisense, and Exavera. In these types of systems, objects and persons can carry small devices to aid the network in determining their location.

We think that the network-centered model is more appropriate for the type of scenarios that take place in hospitals, which are our focus for technological development. In a hospital environment some artifacts, such as wheelchairs, stretchers, portable EKG equipment, and others, are good candidates to be located. Moreover, the network-centered model allows the possibility of continuous tracking.

REPRESENTATION OF PHYSICAL SPACES

It is necessary to have a computational model to represent all those artifacts and persons that are moving within a physical space. This model should represent, at least, the physical space, the entities that move within it, as well as those that are static. There are currently different models that allow the representation of physical spaces (Rui, Moreira Rodrigues, & Davies, 2003), including the geometric model, set theory, graphs, and the semantic model. The geometric model includes definitions based on Euclidian geometry, through coordinates in a Cartesian plane; this plane is a direct consequence of cartographic representation, where information and participating entities are superposed on maps, planes, or images. The semantic model offers descriptive information about the geometric areas that represent physical spaces. Under these considerations, both the geometric and semantic models are appropriate for the requirements and technological needs identified in the type of environments that we are interested in (i.e., hospitals). These models have been previously used in the projects and commercial systems mentioned above, namely Cricket, RADAR, Exavera, Ubisense, and Radianse.

PROXIMITY MODEL

A fundamental concept for proximity-based service discovery is, not surprisingly, proximity. The key for a correct association between services and physical spaces is the geographical criterion to be used when services are searched based on their proximity. Two models are widely used for the selection of services: the distance-based model and the scope-based model. In the distance-based model, clients select the services that are within a certain distance from the current position. Given that proximity is a relative value and what is perceived as proximal can vary drastically according to the activities being performed by the client, some mechanism should be present to dynamically change the proximity range.

In a scope-based model, each service is associated with a scope that explicitly represents the context of use of the service within a physical space. The client selects those services whose scopes include the location of the requesting client; that is, a client can discover services if it is inside a certain scope, as well as the services. The main characteristic of this model is that the correlation between context and proximity is assured. When services are discovered, no matter what their distance, they have a high probability of being relevant for the requesting client.

We consider that the scope-based model better suits our needs, mainly because it allows the representation of physical sub-spaces as geometric shapes; this is very adequate for indoor environments such as hospitals where the definition of rooms, working areas, and so on is very useful.

DEFINITION OF SERVICES

A service is an entity that can be used by a person, a computer program, or any other entity (Johansen, 1999); examples of services are files, a storage device, a printer, a server. When service discovery is performed within a physical space or