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# Indoor location based services challenges, requirements and usability of current solutions

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ABSTRACT

Indoor Location Based Services (LBS), such as indoor navigation and tracking, still have to deal with both technical and non-technical challenges. For this reason, they have not yet found a prominent position in people's everyday lives. Reliability and availability of indoor positioning technologies, the availability of up-to-date indoor maps, and privacy concerns associated with location data are some of the biggest challenges to their development. If these challenges were solved, or at least minimized, there would be more penetration into the user market. This paper studies the requirements of LBS applications, through a survey conducted by the authors, identifies the current challenges of indoor LBS, and reviews the available solutions that address the most important challenge, that of providing seamless indoor/outdoor positioning. The paper also looks at the potential of emerging solutions and the technologies that may help to handle this challenge.



## 1. Introduction

Location Based Services (LBS), such as navigation, Location Based Social Networking (LBSN), asset finding and tracking, are used by many people widely around the world [1,2]. About three quarters (74%) of smartphone device owners are active users of LBS [3] (Pew Research 2013). However, when used indoors, applications have difficulty providing the same level of positioning accuracy, continuity and reliability as outdoors [4]. Global Navigation Satellite Systems (GNSS) are the most widely used positioning technology for outdoor use [5]. However their signals can be easily blocked, attenuated or reflected [6]. This makes them unreliable indoors, making it impossible to seamlessly use them for positioning across outdoor and indoor environments. Many life-saving services, such as for emergencies and security, could be improved hugely if indoor LBS could address this challenge. In addition, although people spend most of their time inside, indoor LBS generates less than 25% of total revenue (ABI research 2015). If LBS could overcome these challenges, its market will develop and more users will be attracted. This paper identifies these challenges using a survey of the latest research and the results of a survey conducted by the authors. The paper also evaluates current solutions and uses this analysis to identify the most suitable solution among those currently available.

Research into the challenges presented by LBS is on-going [4,7–9]. This paper considers their findings, in addition to a comprehensive survey targeting ordinary LBS users, application developers, component providers and companies, market analysts and content providers. This synthesizes both the technical and non-technical challenges in one study. The most important challenge identified by this paper is providing Quality of Positioning Services (QoPS) — the functional and non-functional parameters that include accuracy, availability, and cost (both to the user and for infrastructure deployment) including the availability, continuity, and accuracy of positioning services for indoor use. Other major

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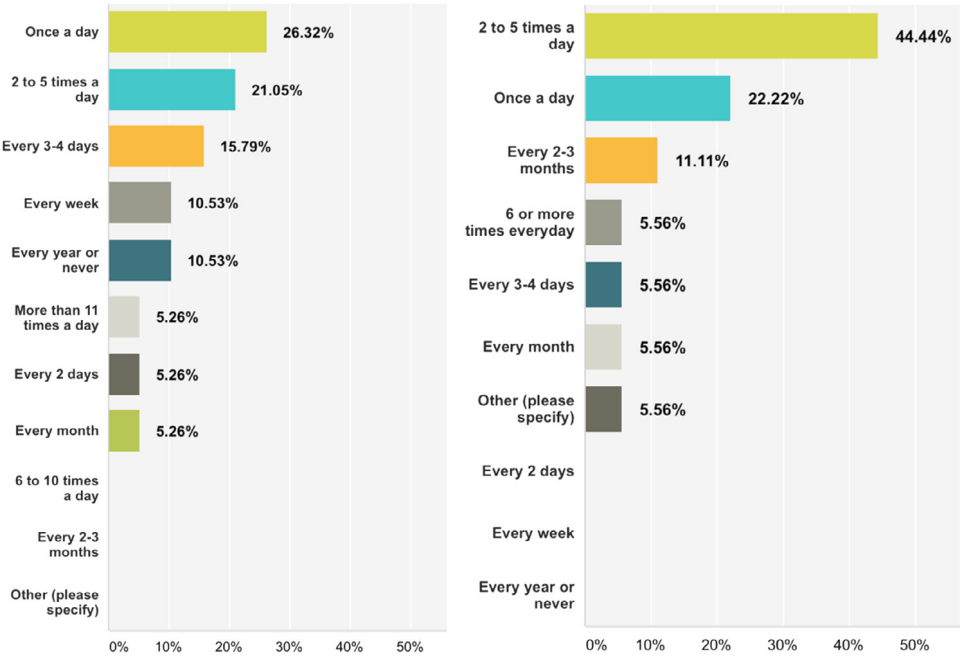


**Fig. 1.** The frequency of use of the location-enabled devices (left) and applications (right) by ordinary users of LBS.

challenges are identified as concerns over privacy associated with location data and the overall cost of services.

Some of these challenges, including accuracy and reliability, are directly linked to the effectiveness of positioning technologies while others, such as cost and privacy, are closely related to them. However, there are some issues that are independent, such as the business model used and the social acceptability of an application. The latter have been reviewed elsewhere [10].

This paper reviews the technologies which are currently being used as solutions to these challenges. Also, based on the results of a survey, a literature review and analysis on the available systems, this paper compiles the requirements of current LBS applications. By comparing the technological requirements of LBS applications and the available solutions, the paper assesses the usability of the current technologies for five application categories.

In addition, an analytical tool is described to evaluate the usability and fitness-to-purpose of each positioning technology for specific applications. The application requirements might differ slightly from the general category it falls into. This tool uses the Analytic Hierarchy Process (AHP) [11] to select the most appropriate technology among those currently available according to the positional requirements for the application. AHP is a powerful tool for systematic multi-criteria decision-making. The developed tool is sufficiently flexible that it can assess new LBS applications, which are currently emerging very frequently.

In section two, the structure of the survey and the process of the identification of LBS challenges and requirements are explained. Section three studies the current solutions to the identified challenges and a usability analysis tool is introduced and used.

## 2. Identification of indoor LBS requirements and challenges

Although some of the challenges in the development of LBS are shared by a wide range of applications, their impact can vary from one application to another. For example, the availability and the accuracy of indoor positioning services is one of the major obstacles for indoor applications. The main positioning technology, Global Navigation Satellite Systems (GNSS) such as GPS, is not usually available. A lack of accurate positioning is a major issue for tracking and navigation services. However, in advertising and social networking applications, a hundred-meter locational error might be satisfactory. Therefore, if we separate LBS applications into categories, we can identify the shared issues within each. This section describes the process of identifying each application's requirements, its categorization based on this, and the implementation challenges. This is based on a literature review and the results of a survey.

### 2.1. Survey structure and participants

The web-based survey, conducted in May 2015 for three months, had 245 participants (212 valid responses), aged between 18 and 73 years, with 164 male and 48 female respondents. The distribution of 212 participants and their level of expertise in LBS are shown in Table 1.

The frequency of using LBS applications and the number of devices owned with positioning capabilities varied among the different participant groups. However, across all a minimum of 52.63% of the users have three or four devices with positioning capabilities, such as mobile phones, vehicle satellite navigation, fitness devices, iWatch, iPod, iPad), and a minimum of 44.44% on average use their location-based devices at least twice a day. The frequency of using LBS applications by the largest participant group (LBS ordinary users) is shown in Fig. 1.

### 2.2. LBS application segmentation

The participants were asked about the frequency of use of several applications, including navigation, tracking, emergency and safety, local news, location-based social networking, travel guidance, elderly assisted living, and pet/asset finding. The participants were asked about the important features of these that they would consider when buying, downloading or in use. For each application, the participants were asked to rank the features by importance to them, including the cost of first purchase, update fees, battery consumption, user-friendliness of the interface, size and weight (of the device), location accuracy, continuity of service (seamlessly indoor/outdoor), delay in providing service, and privacy features. The participants were also asked about their