Seamless Indoor/Outdoor Positioning with Streamspin

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ABSTRACT

This paper presents the implementation of a novel seamless indoor/outdoor positioning service for mobile users. When users are not within GPS range, the service exploits the wifi access point infrastructure for positioning. A central server stores wifi radio maps and map images that are then sent to user terminals based on the mac addresses of nearby access points. The positioning services is available in Streamspin (`www.streamspin.com`), which is an open and scalable platform for the creation and delivery of location-based services. With this new service, the system enables the easy creation and deployment of mobile services that rely on seamless indoor/outdoor positioning.

1. INTRODUCTION

Location Based Services (LBSs) have long been dubbed as the next "killer apps," but have yet to realize their potential. One major obstacle is that geo-positioning is neither truly ubiquitous nor hassle-free. With the proliferation of GPS-enabled mobile devices that support wifi communication, it is possible to reduce this obstacle.

Another obstacle is the lack of service "integration" [5]. Currently, most LBSs are designed to support a single purpose, and users must use multiple services to meet their LBS needs. For example, a GPS-based service such as Nokia Maps [8] may be used outdoor, while different services, e.g., those made available by Ekahau [2] and Blip Systems [1], target indoor use. A related problem is that of the users being able to find the relevant services in the first place.

The company Skyhook Wireless [11] makes strides towards ubiquitous LBS by providing indoor and outdoor coverage with an accuracy of 20 meters and by establishing collaboration with content providers. However, research on indoor positioning using wifi radio maps of existing infrastructures demonstrates that much better positioning accuracy (< 2 m) can be achieved, thus enabling indoor LBSs that rely on or benefit from more accurate positioning [3, 4, 6, 9]. Further, a more open service setting would allow for more diverse content and functionality.

Streamspin, with its indoor/outdoor positioning service, seeks to overcome the above-mentioned obstacles by encapsulating client-server communication, heterogeneous mobile clients, and positioning behind an easy-to-use web-service interface. This paper presents the seamless indoor/outdoor positioning service that is being made available in Streamspin. In the demo, we will demonstrate how users are capable of transparently receiving location-based content in indoor and outdoor settings. The seamless integration of indoor and outdoor positioning is achieved by using the existing wifi access point infrastructures of buildings and user-supplied radio maps. The positioning service uses a central server to store radio maps and map graphics that are sent to mobile terminals when suitable access points are in range. The service makes it possible to tracking users and provide them with services even if they are out of GPS range.

The paper is organized as follows. First, a general overview of the Streamspin system is given in Section 2. This is followed by a detailed explanation of the outdoor-to-indoor positioning handover in Section 3. Finally, Section 4 concludes and presents research directions.

2. THE STREAMSPIN SYSTEM

Streamspin [10](`www.streamspin.com`) is a platform for the creation, sharing, and deployment of location- and context-based mobile services. The system is open, scalable, and offers easy-to-use service creation and subscription interfaces. By encapsulating the server-to-client communication and the heterogeneity of mobile terminals, the system enables developers to overcome the worst hassles in developing LBSs. The system allows service developers to push content (HTML) to the mobile terminals using a simple web-service interface. In addition, service developers can track terminals with accuracy guarantees, by issuing subscriptions that, upon user acceptance, ensure that notifications are received whenever a terminal moves by more than a given threshold. Streamspin also enables service providers to advertise services in a service directory, from where users can then subscribe to available services.

Streamspin is an evolving platform that is used as a test bed for data-management techniques relating to location- and context-aware services. The system is freely available to developers and users, and everybody can develop and

MobiQuitous 2008 July 21 - 25, 2008, Dublin, Ireland.

consume services. With flat-rate mobile Internet and dramatically decreasing pay-per-use rates, use of the system is inexpensive for regular users.

3. INDOOR/OUTDOOR POSITIONING

In order to continue to perform tracking and supply services when users are out of GPS range, Streamspin implements a central location data store where content providers can add new buildings. Each building is assigned a unique ID, and the content provider provides a list of available access points, a wifi radio map used for indoor localization via access points' signal strengths, and graphical floor maps to display the users' position and points of interest in the building.

The Streamspin client contains a module, *WifiLocationProvider*, for locating a relevant building and performing indoor positioning when the GPS signal is lost. The outdoor-to-indoor positioning handover is handled as follows (see Figure 1): When the GPS signal is lost, the terminal scans for nearby access points (APs) and puts the MAC addresses of the available APs in a list. The list is sent to the server-side building container that returns the ID of the building that matches the most MAC addresses—this matching is necessary because adjacent buildings may share overlapping access points

The client then checks whether a radio map of the building is stored on the device. If not, a radio map is fetched from the server. With the radio map present on the device, the positioning loop starts. It raises a "location-changed" event on each new location estimate. The positioning loop terminates when the wifi connection is lost or it is terminated by the user. The client device performs self-localization in order to avoid excessive communication with the server.

If a user opts to have his or her location shown on a map, a similar sequence of events occurs. First, the device checks if a map of the building is already present. If not, a map of the current floor (as estimated by the localization algorithm) is fetched from the server, upon which visualization starts.

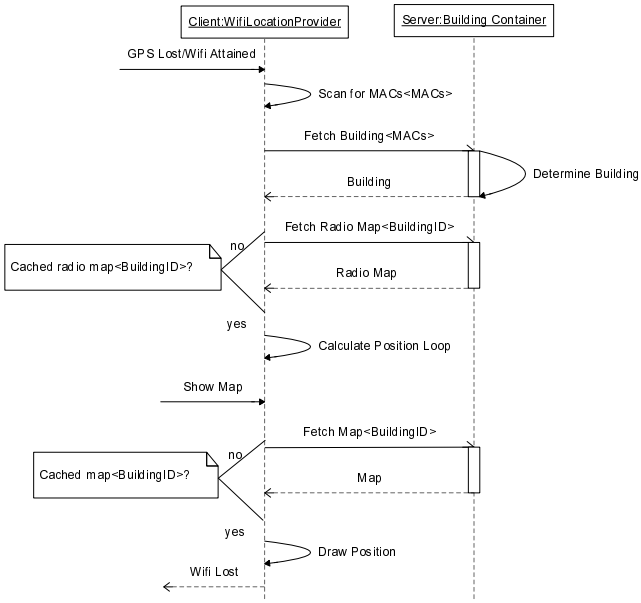

Figure 1: The sequence of events that occurs on the transition from outdoor to indoor positioning

4. CONCLUSION AND RESEARCH DIRECTIONS

This paper offers an overview of the integration of a seamless indoor/outdoor positioning service into a system for supplying location-based services. The service allows continuous tracking of users across outdoor and indoor settings using a simple handover mechanism. It also supports the automatic discovery of wifi infrastructures suitable for positioning using a central radio map and map graphics server. Users can supply their own radio maps and graphics, i.e., the open and user-driven structure of Streamspin is retained.

Several interesting areas require further investigation. As users can upload their own radio maps, a building may have several maps. User involvement may be exploited in order to identify the best radio map, e.g., using feedback mechanisms such as user-supplied quality ratings. With the ever increasing bandwidth of the mobile Internet it may also be interesting to pre-fetch maps using GPS positions; this may yield a better user experience.

Another improvement that is currently being implemented concerns the use of building maps that conform to the IFC standard [7]. IFC is an open, interoperable building format that contains additional, useful information. This includes semantic content about rooms or areas, as well as information about construction materials that may be used by signal propagation models to create radio maps without human intervention. Finally, the IFC model enables the display of 3D maps on mobile terminals.

5. REFERENCES

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