Integration of Indoor Positioning into a Global Location Platform

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Abstract – **The availability of positioning information for short range wireless networks, especially in in-door environments, can enable a broad variety of location based mobile services. In this paper, we discuss current indoor positioning systems based on Wireless LAN and incurred performance issues resulting on implementation and application requirements. Our approach extends conventional indoor positioning systems by introducing a homogeneous interface between outdoor-based (e.g. cellular networks, GPS Systems) and indoor-based positioning systems (e.g. WLAN or Bluetooth Networks). Furthermore, we discuss several positioning methods and show how geodesic methods can improve positioning methods, especially during positioning system initialization.**

1 Introduction

Apart from the inter-technology handovers required for seamless service provisioning moving between outdoor and indoor environments requires a complex interaction between the different natured positioning systems e.g. outdoor cellular/GPS to indoor WLAN/Bluetooth Positioning Systems.

Positioning is the precondition when realizing a location based service. So far there are many different positioning schemes in use depending on the underlying networks. As an overall positioning standard GPS is the most important system for localising mobile users. The last years several approaches were picked up to implement a GPS independent system- only based on the existing infrastructure of a mobile network. This was motivated on one hand by political reasons – GPS is US technology and can be switched on/off or the accuracy can be reduced – and on the other hand by the raising cost caused by additional hardware which is needed for the usage of GPS.
Another shortcoming of GPS is its limitation to outdoor usage. The GPS signal is not strong enough to be received in buildings. Therefore an indoor positioning of a mobile device is not possible.
Positioning methods based on mobile network infrastructure are working anytime the end device has a connection to one or more base stations. Their accuracy differs from a few meters (triangulation) to several kilometres (cell-based positioning in rural regions) and depends on the network (WLAN, GSM, etc.) as well as on the implementation.
The aim of this paper is to propose a homogeneous positioning interface independent of the actually used positioning scheme. The location system should always select the "best" method for localising a device. In addition we also introduce a very accurate indoor positioning method for wireless LAN. Without considering the fact that GPS does not work in buildings this method is able to determine the user's position up to a few meters which mean a much higher accuracy than normal GPS offers.

Clearly, GPS sets the current standard and best positioning accuracy for outdoor environments. Depending on the visibility of GPS satellites in the current region, as well as obscuring obstacles such

as tall buildings and cloudy weather conditions (e.g. snow) resulting in signal multipath and dampening errors respectively, positioning accuracies between 4-25m are easily achieved.
For indoor environments, positioning systems relying on existing network infrastructures such as WLAN or Bluetooth are able to provide location accuracies roughly ranging from 1-10m, depending heavily on the usage environment. Recent developments in this field and some commercially available products range from site mapping software to indoor navigation and tracking systems [2]. Based on signal strength location measurements, highly dynamic environments and changing location infrastructure are the greatest cause of location estimation inaccuracies.

2 Indoor Localisation Schemes

We use three different positioning techniques for providing the optimum calculated positioning information: Cell-based, signal triangulation and signal fingerprints [1] [7]. Especially, the signal fingerprint method provides the best accuracy (1-2m), using 3-4 access points. It matches measured signal strengths against signal profiles (e.g. rooms, halls) generated during the initialization phase. Hence this technique requires much more reference signals, hence prolonging the initialization phase. Furthermore, major changes in the environment (e.g. rearranging office furniture and PC Terminals), have major impact to the signal profiles, hence need a re-initialization phase. More information about the initialization and location system calibration issues, as well as approaches on how to further improve the positioning accuracy by means of probability calculations, can be obtained from here: [6]

In the following section, two positioning-algorithms namely the Triangulation and a Finger-Print-method are described more specifically. Both are implemented in our solution.

2.1 Triangulation

In the two-dimensional case at least three access points have to be receivable. Each signal strength is sent to the Location Server by the mobile device. The Location Server then calculates the distance between the access point and the mobile device. Additionally these distances are used as radii of circles with the specific access point as centre. In theory the point of intersection of the three circles describes exactly the position of the mobile Station. In practice due to damping and reflection you can never calculate the exact distance and therefore no common point of intersection of three circles exists. The algorithm in this solution calculates each point of intersection of each circle-pair. At most six Points are calculated. If no Point of intersection of a circle-pair is calculated one has to be constructed. The next thing is to figure out which three points describe the most probable area for the mobile device. These are the three points with the shortest distance to each other.
Finally the geometrical-centre describes a possible position of the mobile device.

This algorithm was tested at 176 randomly chosen Points at the CDTM in Munich. The surrounding was at the third floor of the building. 44 Calibration Points are used to create the functions for calculating the distances. The average error was 4.8 metres.

2.2 Finger-Print-method

Calibration data consists of the specific location of all calibration points and the signal strength of each received access point at a specific calibration point. This data is stored in a database at the Location Server. If a LBS requests the position of a mobile device the algorithm works as follows:
The current signal strengths received by the mobile device are compared with the measured signal strengths of each calibration point in the database. The calibration point with the most similar signal strengths describes approximately the position of the mobile device. This comparison is implemented by using the Euclid distance. The average value of the last nine positions and the current position is the final position. That is an easy way to handle ambiguities which could occur if calibration points at different places have almost the same signal strengths.

This algorithm was tested at the same surrounding as the Triangulation. 176 calibration points with signal strengths were stored in the database. This solution has a precision of 1 to 3 metres.

3 Architecture

Our WLAN Positioning Architecture has a client and server side component. The WLAN enabled client uses a slim software agent, which collects the signal strength information of nearby access points and transmits them in regular intervals to our location server.
The architecture of our platform divides into three logical parts: The Mobile device(s), the Location Based Services (LBS) Server and the location server (LS). The functional mapping is based on the layered approach suggested in [5].
The supported Mobile Devices can be PDAs or laptops, which are equipped with a WLAN interface within radio coverage of a WLAN Access Point in the database. The location server holds the signal strength site map calibration information of the WLAN Access Points. Additionally, two functions (Java Servlets) allow access to the database. The Signal_Strength_Reciever, agent periodically receives signal strength information from the roaming clients. The Positioning_Calc agent receives positioning requests of clients by the LBS Server, calculates the position using our three positioning algorithms and returns the best possible positioning coordinates.
The LBS Server contains hosts LBS Services and provides a common LES interface for positioning requests. This interface is an extension of the Siemens LES API 2.0 [3], hence making it possible to process positioning requests from either mobile phones (GSM positioning) or WLAN capable terminals. Positioning requests received via this interface are forwarded to the appropriate location server. The clients are identified by their MSIDN or WLAN MAC Address respectively. Figure A below demonstrates a typical WLAN terminal positioning request.

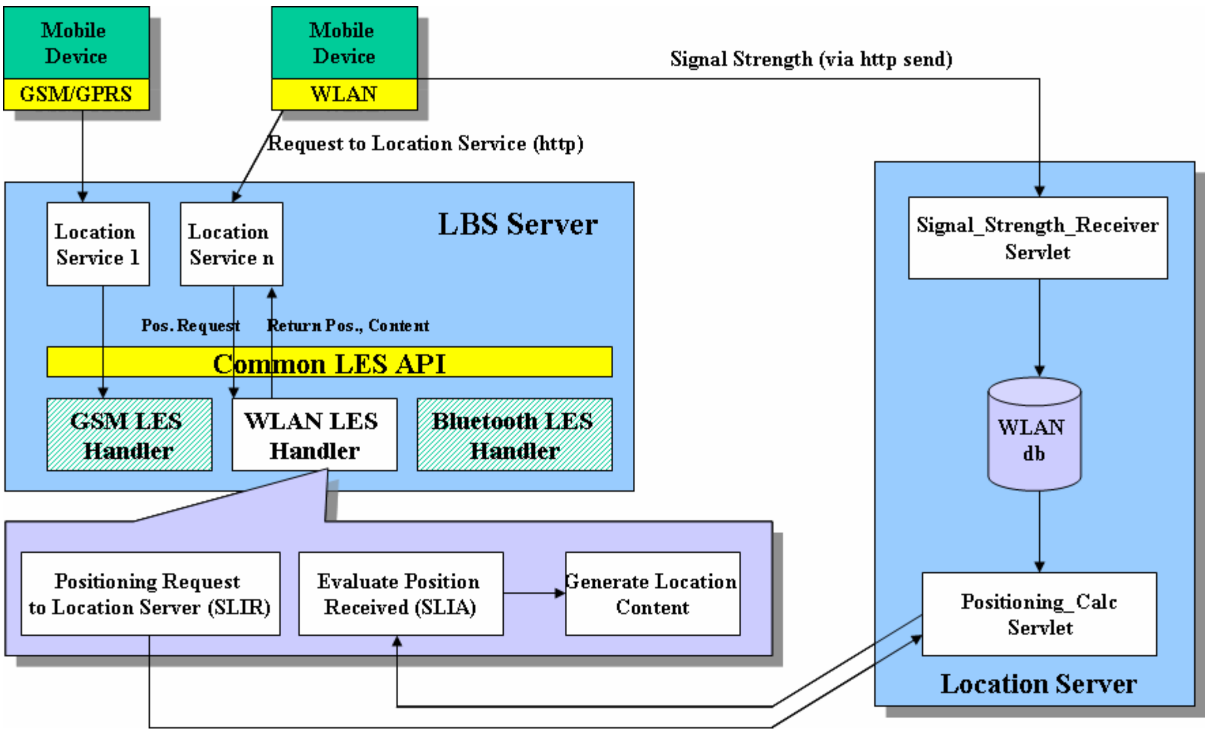

Figure A – Architecture Overview

The common LES interface provides the first step towards a homogenous positioning API for positioning over heterogeneous networks. Further extensions to the common LES interface such as Bluetooth-based positioning, and enhanced user profiles (history caching of positions and improved AAA) are being developed.
The Location Server Architecture (Figure A) is showing how location requests are forwarded to the appropriate positioning (LES) handler. The GSM Handler access an external LES 2.0 server hosted by our Vodafone Project Partner [4]. The Bluetooth Handler will be implemented in the near future.

4 Reducing Measurement Error by geodetic measurement methods

The quality of the finger print method is clearly related to the quality of the underlying table containing signal strengths and the corresponding positions. Therefore, the training period for the finger print method has to occur with great care. Since geodesy or surveying uses horizontal and vertical angle measurements as well as distance measurements to calculate the exact Cartesian position of objects in 3D, the inclusion of geodetic services has two advantages for an indoor positioning system based on the finger print method using the signal strengths of a WLAN.

Firstly geodetic transformations realise the integration of a local coordinate system used in the WLAN environment into a national or even global reference frame – such as the WGS84 – which can be used as an interface to other (in general outdoor-) positioning systems as the Global Positioning System (GPS).

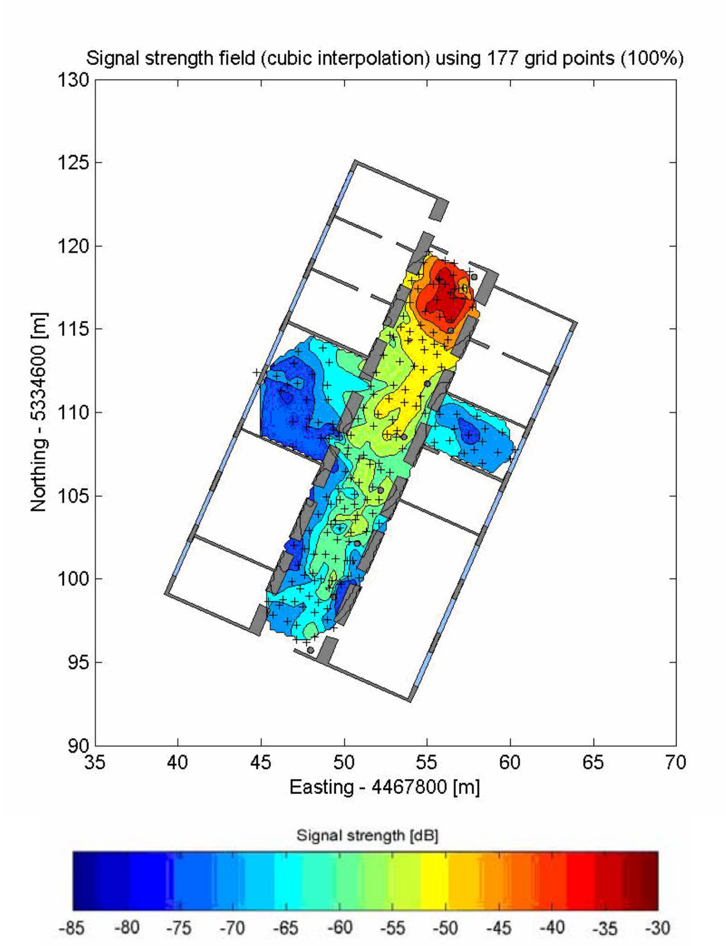

Figure B – Signal strength and Interpolation

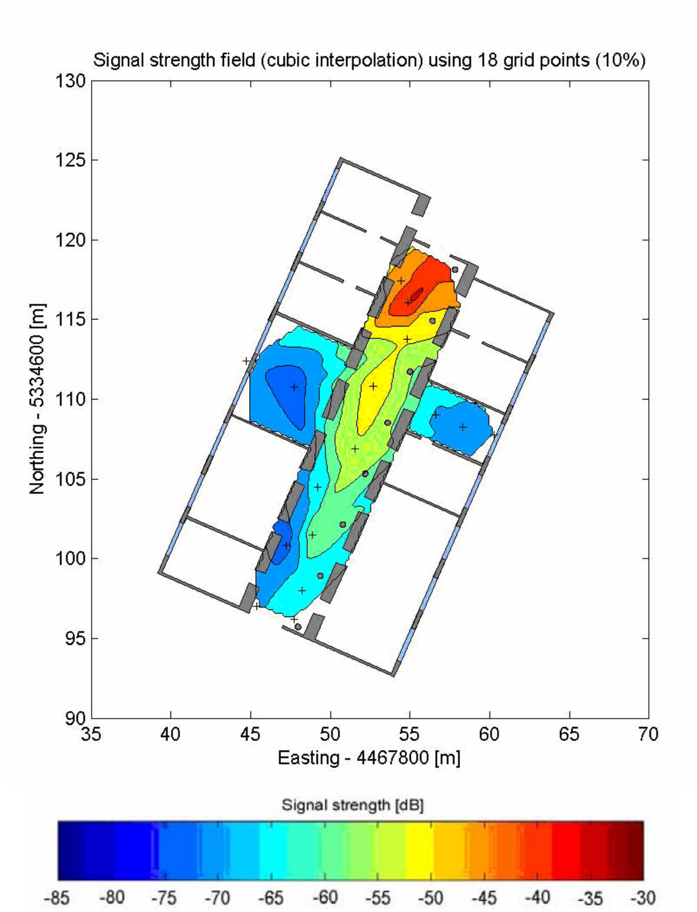

Figure B (continued)– Signal strength and Interpolation

Secondly the rather new technology of reflectorless distance measurement – which uses a phase measuring method with a visible laser that clearly marks the target and delivers the distance with a high degree of accuracy – allows the determination of any object's position (e. g. access points and WLAN cards) in a very efficient way.
Therefore it is possible to create a dense test environment which includes besides the signal strengths of three access points the corresponding position of the WLAN card (resp. the user) and the positions of the access points itself within a few millimetres. During the tests at CDTM 177 points within 152 square meters were recorded with a time exposure of 7 man hours.

To reduce the needed effort (especially) for initiating the finger print method we experimented with cubic interpolation algorithm. Figure B (continued) shows the results of our measurements and the interpolation results. With only 10% of the measured signal strengths we could show that the finger print method is still working.

5 Conclusion and Outlook

In this paper we have given an overview about our work. Our aim is to realise a homogenous positioning platform for different network types in different environments (i.e. indoor and outdoor) and to offer service providers the best available localisation. By providing a generic interface independent from the actual used positioning technique developer are able to create location-based services without thinking about integration problems.

To improve the indoor approaches we show how the existing indoor schemes get better by using geodesy methods to increase the accuracy. So far one of the biggest disadvantages is still the initiation effort. Our further work will deal with reduction of installation complexity and development of suitable tools.

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