IMPROVING DIRECTORY-LESS WLAN POSITIONING BY DEVICE WHISPERING

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Abstract: Existing positioning systems do not provide the required positioning accuracy for navigation systems in indoor environments. Novel system approaches are based on fingerprinting and triangulation techniques. Thus, they suffer on low positioning accuracy due to multipath propagation and different sending power of the considered access points. Other approaches are based on tagged *WLAN (Wireless Local Area Network)* access points or *GSM (Global System for Mobile Communication)* base stations with their corresponding position stored in a central tag directory. This would cause high communication costs for a mobile device that queries the directory frequently. In this paper we present a filtering technique for access points to determine the closest ones to the mobile device. The geographical position of the mobile device is calculated from the geo tags broadcasted by the access points in the mobile device's vicinity. Systems based on this approach will provide the same accuracy as directory-based positioning systems at a low cost.

1 INTRODUCTION

Since wireless networks are becoming more present at many places, the vision of ubiquitous and pervasive computing can now become true. However, navigation and guiding systems need the current position of a mobile device to provide the according information to its users' context. Current outdoor positioning approaches are based on GPS that does not works indoor due to the limited reception of GPS signals inside of buildings. This paper proposes a new directory-less approach for WLAN indoor positioning which can be used to realize indoor navigation and guidance systems at airports or railway stations, e.g. to guide the passenger to his gate or to the next restaurant. This approach does not need any additional server infrastructure or additional transmitter antennas, because it uses already existing WLAN infrastructures.

This paper is organized as follows: In section 2 we discuss well known existing positioning approaches applicable in GSM and WLAN infrastructures. Furthermore, we discuss the positioning accuracy for mobile devices provided by approaches presended in the past and the arising expenses for mobile users. Section 3 discusses the proposed approach of SSID-based WLAN positioning by device whispering, the involved components of the IEEE 802.11 WLAN standard, and the push and pull interaction models for SSID WLAN positioning. Section 4 discusses a short application scenario and Section 5 comprises the conclusion.

2 POSITIONING APPROACHES

Positioning systems estimate the position of a mobile device with the help of calculus concerning the attenuation of communication signals send and received by the device. Well known approaches for positioning are: proximity detection and trilateration (or multilateration). Systems based on proximity detection operate upon a set of antennas with well known positions and use the position from the strongest signal (Yeung and Ng, 2007) to determine the position of a mobile device. Systems based on trilateration are using the strength values of three (or more) signals send to or received by a mobile device to estimate its position. Proximity detection requires a dense grid of antennas for a high accuracy which would cause very high installation costs in indoor environments. Trilateration (Staras and Honickman, 1972) (Warren et al., 1972) provides an acceptable accuracy at a lower cost, but suffers on a high influence of environmental changes, e.g. wall humidity in buildings resulting from rain, moving (radio) indoor obstacles like people, etc. An improved version of the trilat-

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eration approach is the envinronment fingerprinting method (Jan and Lee, 2003), due to that for all the rooms in a building a set of radio signal vectors (fingerprints) is collected and saved in a central directory. A device interested in its position will send its actual signal vector to the central directory and the directory will send the closest position to the provided signal vector back to the device.

2.1 Positioning Accuracy of Mobile Devices

Proximity detection in GSM networks could use the Cell-IDs to estimate the position of a mobile device (Kunczier and Anegg, 2004). The very low accuracy of this systems in outdoor scenarios will be worser in indoor scenarios, making them unsuitable for indoor positioning or guidance applications. The accuracy for Cell-ID based approaches could be improved by probability calculus (Borenovic et al., 2005), but not in that matter to make them suitable for indoor positioning. In (Krempels and Krebs, 2008) a new approach for indoor positioning is proposed that is based on geo-tagged WLAN access points and trialteration. The proposed solution assumes that there exists a WLAN infrastructure in that all access points are tagged with their geographical position and mobile devices will use this tags to estimate their position. The accuracy of this system seems to be suitable for guidance and navigation applications inside of large buildings.

Trilateration provides only a very low accuracy in GSM networks, due to the large diameter of GSM network cells (Kos et al., 2006). Thus, it is not very useful for navigation or guidance systems in indoor environments. One way to improve the positioning accuracy is to increase the density of antennas that would increase the network operation costs. However, this is not the objective of the network provider and operator. The deployment of the trilateration approach in existing indoor network infrastructures like WLAN would reduce the costs, but the position estimation becomes difficult due to the different signal strengths of the WLAN access points transmitter and multipath signal propagation (Wallbaum, 2004). The positioning accuracy could be improved with the help of probabilistic calculus, but this is also highly influenced by environmental changes. Benchmarks regarding the positioning accuracy of famous wireless location systems proposed in the past are discussed by Wallbaum and Diepolder in (Wallbaum and Diepolder, 2005).

2.2 Mobile Device Positioning Costs

Wireless positioning systems based on proximity detection in GSM networks using Cell-ID's (Kunczier and Anegg, 2004) (Borenovic et al., 2005) require a directory on the network site that maps a Cell-ID to the coordinates of the corresponding location. This means, that a mobile device must either establish a connection to this directory for each positioning request or must remain connected all the time. Both cases would produce continous positioning costs. A directory is also necessary for wireless positioning systems in GSM networks that are based on trilateration or fingerprinting causing also continuous costs for the positioning of a mobile device.

Trilateration positioning systems for WLAN infrastructures proposed in the past are also directory based (Wallbaum and Spaniol, 2006) (Wallbaum and Diepolder, 2005). To determine its position, a mobile device scans its vicinity for WLAN access points and send this list to a directory server. The server provides the coordinates which are related to these access points. If there is no positive match, the server responds with an error and the client cannot determine its current position. The main drawback of directory based systems is that clients must establish a connection to the directory server that would cause high costs for the positioning information, which is required very often for navigation and guidance applications.

The indoor positioning approach based on geotagged antennas (WLAN access points) proposed in (Krempels and Krebs, 2008) operates directory-less. Therein, the central directory required by other approaches was removed in favour of reduced positioning costs for a mobile device. The approach is suitable for indoor and outdoor scenarios with an existing WLAN infrastructure without GPS coverage.

3 DIRECTORY-LESS INDOOR WLAN POSITIONING

In the directory-less indoor positioning approach based on geo-tagged antennas (Krempels and Krebs, 2008) the *Service Set Identifiers (SSID)* of each WLAN access point encodes the geographical coordinates of the access point. A mobile device with an embedded WLAN receiver will receive the broadcasted SSIDs from a number of access points and could decode their geographical coordinates immediatly.

3.1 Service Set Identifier

In the following we describe the Service Set Identifiers which is defined by the 802.11-1999 (Committee, 1999) standard. For the discussed approach in this paper only the SSID is useful:

- The SSID indicates the name of the WLAN cell which is frequently broadcasted in beacons. The length of the SSID information field is between 0 and 32 octets. A zero length information field indicates the broadcast SSID.
- *Extended Service Set Identifier (ESSID)*: Multiple APs have the same SSID and are connected to a larger cell on layer 2 which is than called ESSID.
- The *Basic Service Set Identifier (BSSID)* is a 48-bit field of the same format as an IEEE 802.11 MAC address. It uniquely identifies a Basic Service Set (BSS). Normally, the value is set to the MAC address of the AP or a broadcast MAC address in an infrastructure BSS.

3.2 Pull Model

In the pull model every wireless access point (AP) broadcasts the same SSID like ’geo’. In the next step the client associates with the AP and gets an IP address with DHCP. In the last step the client will query the positioning service provided by the access point to retrieve the GPS coordinate of the AP. However, due to the long interaction chain this model works but it is not very suitable in a time and energy saving world.

3.3 Push Model

The push model is more efficient with respect to the communication overhead, but limited to querying GPS coordinates only. Additional information cannot be transmitted due to SSID space limitations of 32 characters. Every AP broadcasts a unique SSID which is exactly the coded GPS coordinates of the AP. The client needs only to scan for specific geo SSIDs and selects the geo SSID with the highest signal strength. It is not necessary that the client associates with the base station, because the client can retrieve all information from the already scanned SSID.

An example for the location of the city of Aachen *(longitude:6.1, latitude:50.7667)* in the specified tag format ⟨ `geo :longitude,latitude` ⟩ would be ⟨ `geo:6.1, 50.7667` ⟩ and the corresponding broadcasted SSID `geo:6.1,50.7667`

3.4 SSID WLAN Positioning

The position of the mobile device could be estimated with the help of interpolation calculus, by using only the coordinates of the *m* strongest signals from *n* signals received by the device, or even of a combination of both, e.g. by interpolating the coordinates encoded in the *m* strongest signals. However, the result will be an area or even a space, and the position of the mobile would be close to its center of gravity (in the ideal case).

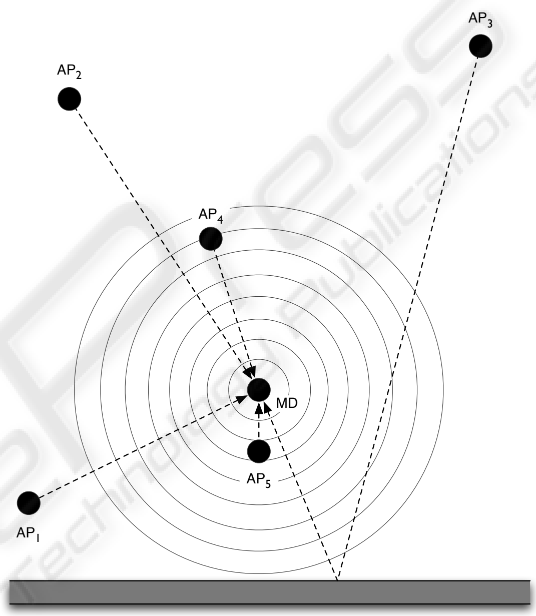

Figure 1: WLAN SSID-Positioning.

Determining the position of the mobile device only with the help of the strength of the received signals is highly influenced by the different sending or changing sending power of the considered access points. Thus, we could not assume forthermore, that the strongest signal is received from the closest access point. In Figure 1 the signal received from AP_4 could be stronger than the signal received from AP_5.

3.5 SSID WLAN Whispering

In Fig. 1 the mobile device *MD* receives the signals and SSID’s from the access points $AP_1, AP_2, \ldots, AP_5$. To select the closest geographical vicinity of the mobile device, we introduce the *whispering approach*. Due to the fact that a mobile device is able to control its WLAN radio interface it can control also its sending power. The characteristics of its receiving antenna are not influenced thereby, so that the list of access points received by the mobile device would not change. WLAN radio whispering consists in reducing the sending power of a mobile device to a minimal value and queriing a subset of the visible access points for management information (Fig. 2).

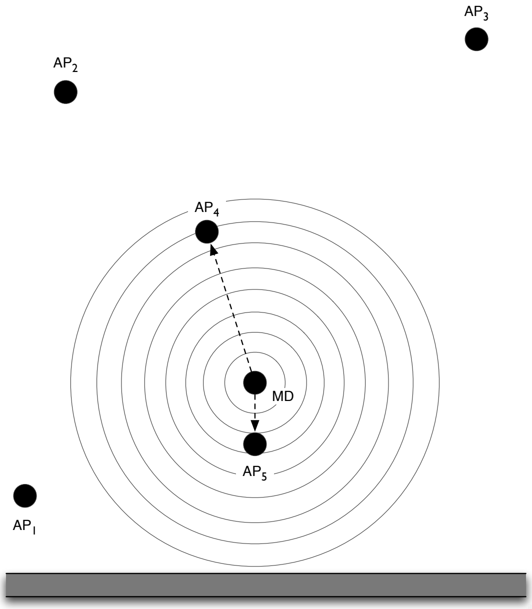

Figure 2: Radio Whispering to Detect the Close Vicinity.

Due to the reduced sending power of the mobile device only the access points, that are geographically very close to the mobile device will receive its query and will answer to it. Thus, the effect of whispering is a filter that is robust against signal multipath propagation and power oscillations or automated adaption of access points. An idealistic abstraction of the whispering effect is shown in Fig. 3.

In the WLAN communication range of the mobile device *MD* the access points $AP_1, AP_2, \ldots, AP_5$ are visible (Fig. 1). AP_4 and AP_5 will receive the information query send with very low power by the mobile device (Fig. 2) due to their close vicinity to it. Access point AP_5 answers to the query (Fig. 3) and the mobile device can extract its position from the SSID of AP_5.

4 APPLICATION SCENARIO

Many indoor navigation and guidance applications suffer on high positioning costs and on low positoining accuracy. The business cases of a subset of this systems are based on low cost or free positioning and do not require high accuracy positioning. Thus, it seems that even with a low positioning accuracy

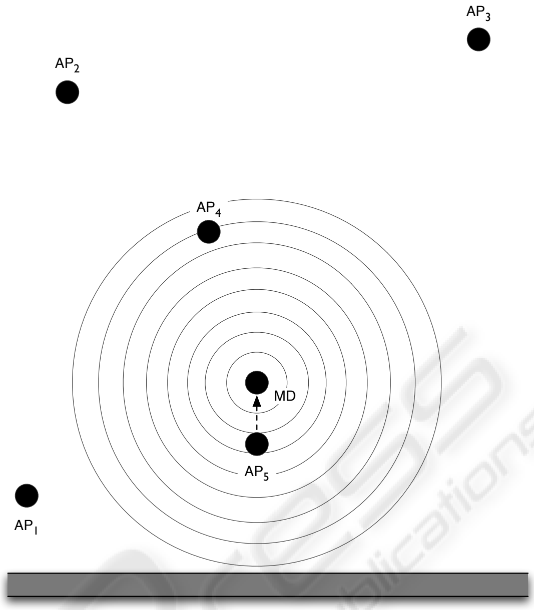

Figure 3: Answer of the Close Vicinity.

(less than twentyfive meters) navigation and positioning applications could be deployed and used. In Fig. 4 a guidance scenario is shown that could be implemented with the help of the positioning approach discussed in this paper. The scenario is based on a planned trip consisting of a travel chain. Each element of the chain has an expected duration and a travel mode (e.g. walking, flying, travalling by bus, etc). For the most travel modes the operation vehicle (e.g. bus, train) and its route is known in advance. Thus, the positioning accuracy could be improved if a determined (rough) position is mapped to well known trajectories of a planned route at the respective time, e.g. corridors, stairs, etc. The scenario in Fig. 4 shows a travel chain element with the travel mode walking. A traveller is guided with the help of discrete position points mapped to his planned route to the right gate, e.g to take his plane.

5 CONCLUSIONS

In this paper, we presented the whispering technique to improve the positioning accuracy in directory-less indoor WLAN positioning. The advantage of this approach is that there is no need to establish an online Internet connection, and that it applicable indoor and outdoor. The positioning accuracy is determined by the radio range of the access points which could be *seen* by a mobile device, and the WLAN radio of the device itself. The proposed solution enables mo-

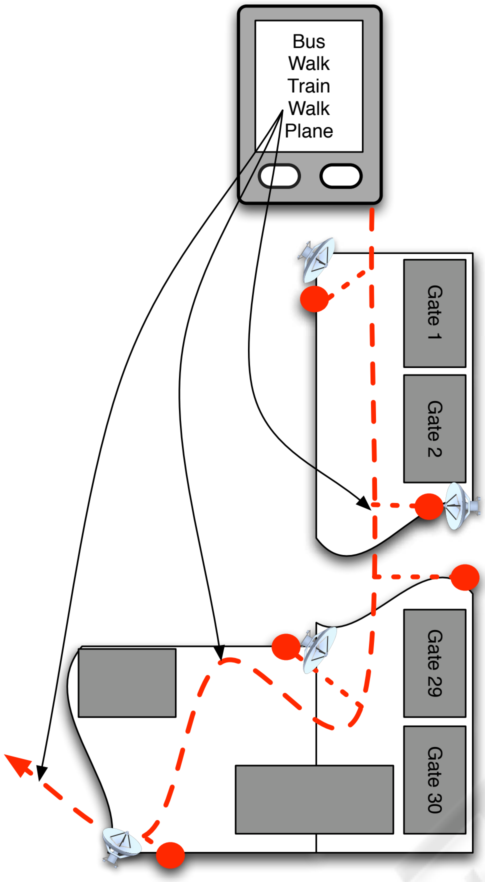

Figure 4: Application Scenario.

bile devices to be used in large indoor environments with an existing WLAN infrastructure for guidance and navigation, e.g. for ealderly people in airports, train stations, etc. In a next step the solution will be integrated in a hybrid positioning system, based on GPS, GSM, and WLAN. The short term objective is to provide a directory less, best effort positioning system.

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