EVALUATION OF 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. The evaluation of the approach shows that the positioning accuracy is limited by the technical capabilities of the radios embedded in today's mobile devices and the provided driver software.

1 INTRODUCTION

Wireless networks become more present at many places and the vision of ubiquitous and pervasive computing becomes true. The current position of a mobile device is important for navigation and guiding applications as well as for the determination of a mobile user's context. Since outdoor positioning approaches are based on GPS, that does not work indoors, due to the limited reception of GPS signals inside of buildings, there is a need for indoor positioning systems.

This paper discusses a directory-less approach for WLAN based 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 the already existing WLAN infrastructure.

The paper is organized as follows: In section 2.4 we introduce the WLAN whispering approach and discuss its merits and flaws. Section 5 discusses a guiding application scenario for an airport. Finally, in section 6 we summarize the results of our work and address open problems in this area of research.

2 DIRECTORY-LESS INDOOR WLAN POSITIONING

Approaches for indoor positioning based on WLAN signals are discussed in (Jan and Lee, 2003) (Wallbaum and Spaniol, 2006) (Wallbaum, 2004) (Yeung and Ng, 2007) (Kaemarungsi, 2006) (Zhao et al., 2008), accuracy comparisons are given in (Lin and Lin, 2005) (Wallbaum and Diepolder, 2005) (Liu et al., 2007).

Directory-less indoor positioning based on geotags is discussed in (Krempels and Krebs, 2008a) (Krempels and Krebs, 2008b). In this approach the geographical coordinates of the access points are directly provided by the access points them self. A mobile device with an embedded WLAN receiver analyses the signals from the adjacent access points combined with the received information on their positions and calculates its own geographical position.

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2.1 Service Set Identifier

Service Set Identifiers are defined by the IEEE 802.11-1999 (LAN MAN Standards Committee, 1999) standard. For the approach of discourse only the SSID is useful:

- The SSID indicates the name of the WLAN cell that is broadcasted in beacons. The length of the SSID information field is 0 to 32 octets.
- *Extended Service Set Identifier (ESSID)*: Multiple APs with the same SSID are combined to a larger cell on layer 2. This is 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.

To supply the geographical coordinates of the wireless access points to the mobile device the following two interaction modes can be used:

2.2 Pull Model

Every wireless access point (AP) broadcasts the same SSID like 'geo'. Then, the client associates with the AP and obtains an IP address over Dynamic Host Configuration Protocol (DHCP). Finally, the client queries a positioning service provided by the access point to retrieve the GPS coordinate of the AP.

2.3 Push Model

Every AP broadcasts a unique SSID that encodes the GPS coordinates of the AP. The client needs only to scan for specific geo SSIDs and selects the 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 received SSID broadcast.

2.4 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 by a combination of both approaches. Meaning, first selecting the m strongest signals and then interpolating the coordinates related to this signals. However, the result will be an area or even a space.

Determining the position of the mobile device only with the help of the strength of the received signals is highly influenced by the changing environment and the changing sending power of the considered access points. Thus, we can not assume, 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.

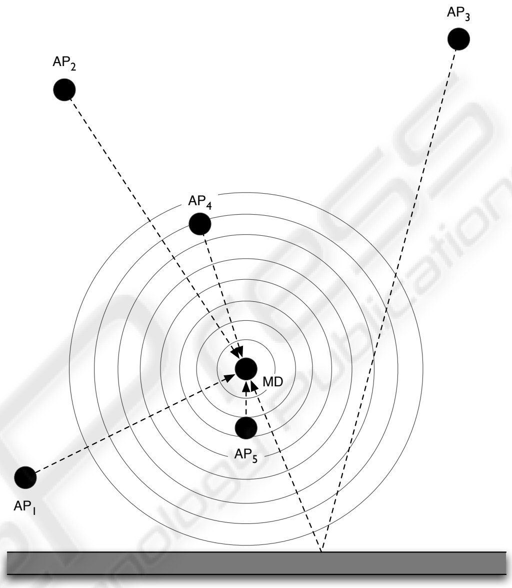

Figure 1: WLAN SSID-Positioning.

2.5 SSID WLAN Whispering

In Fig. 1 the mobile device *MD* receives the signals and SSID's from the access points $AP_1, AP_2, \dots, AP_5$. To select the closest geographical vicinity of the mobile device, we introduce the *whispering approach*. Since 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 (Krempels and Krebs, 2008b) consists in reducing the sending power of a mobile device to a minimal value (less than 1mW) and querying a subset of the visible access points for management information (Fig. 2).

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 multi-path propagation and power oscillations or automated adaption of access points. An idealistic abstraction of the whispering effect is shown in Fig. 3.

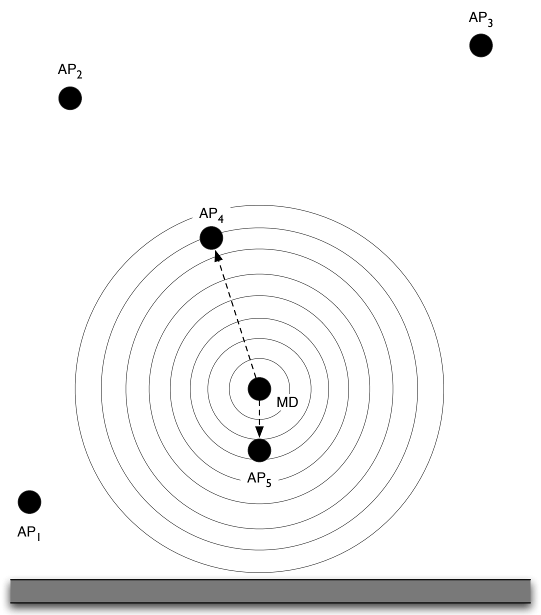

Figure 2: Radio Whispering to Detect the Close Vicinity.

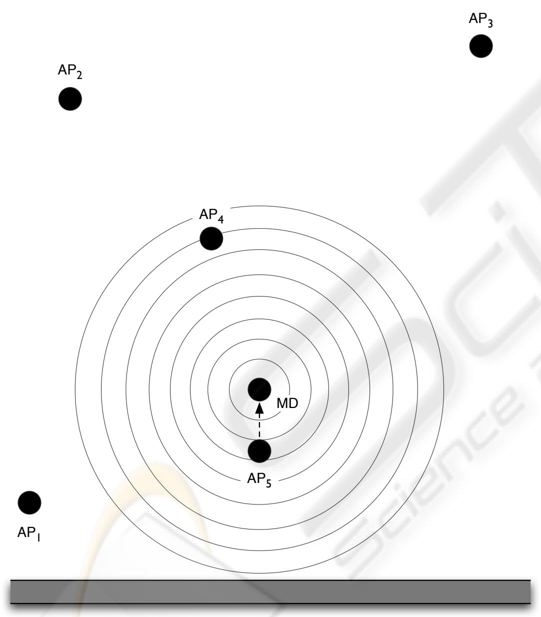

Figure 3: Answer of the Close Vicinity.

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.

3 EXPERIMENTAL SETUP AND ENVIRONMENT DESCRIPTION

Device whispering requires control of the signal sending power at hardware level and a corresponding driver that provides this functionality to application software. Since only a few network drivers met this requirement Linux was chosen as development platform providing a suitable open source driver. Fig. 4 shows the architectural diagram of the implemented software.

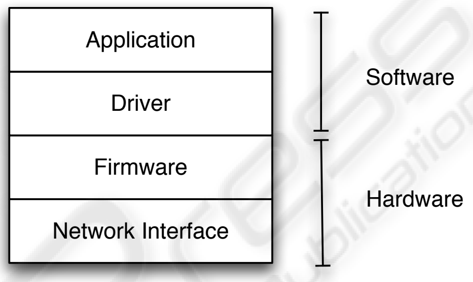

Figure 4: Software Architecture.

The developed application collects the positioning information from the access points requesting the operating system driver to scan the wifi network. Thus, the wireless network interface is instructed with the help of firmware functions by the wireless interface driver to perform the required network scan, then to reduce the sending power to 1mW, and to send out probe request packets to access points with tagged SSIDs.

All measurements for the evaluation of the device whispering approach have been taken at Cologne International Airport[1]. The airport building consists of two terminals Terminal 1 and Terminal 2 with three floors. In both terminals the third floor is the departure level. The arrival level is situated at floor 2 in Terminal 1 and at floor 1 in Terminal 2. In Terminal 1 the three floors have a common open side close to the elevators and the stairs. Thus, the WLAN signal strength varies very much in this area, due to the high dependency of the signal quality from the position and direction of the mobile's WLAN radio antenna. For the validation of the approach we tagged a set of 13 WLAN access points operated by the computer center of the airport with geo tags. Five access points are installed in Terminal 1 at departure level, six access points in Terminal 2 at departure level, and 2 access points in Terminal 2 at arrival level. Figure 5 shows a sketch of the airport building and the position of tagged access points.

[1] Cologne International Airport

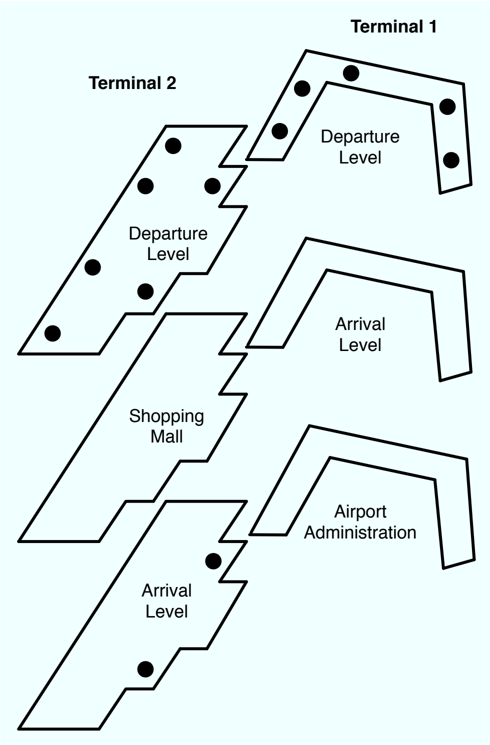

Figure 5: Position of the tagged access points in the airport building.

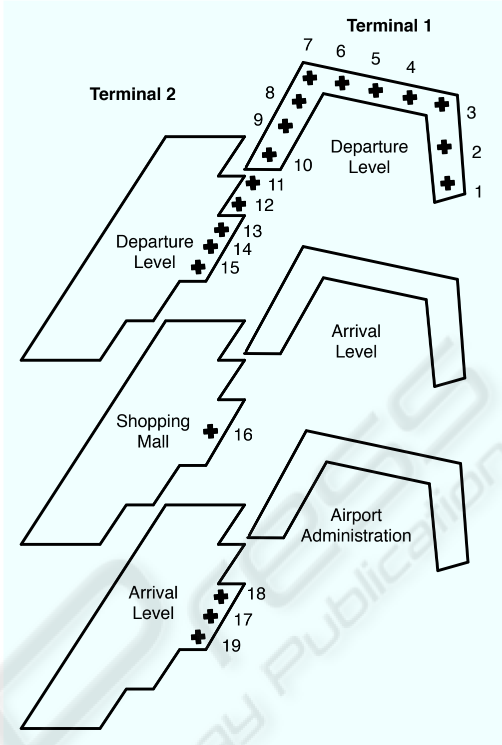

Figure 6: Position of the tagged access points in the airport building.

4 EVALUATION

Figure 6 shows a sketch of the airport building and the position of measurement points 1-19. At each of this measurement points the real position was determined manually to get a value to compare to. Then the position was measured by triangulation with the access points. Once using the old approach and once using the new whispering approach. This was done two times to get an idea of the stability of the measurements. The deviation of the measured positions from the actual positions is shown in Figure 7 not using whispering and in Figure 8 using whispering.

If we look at the figures and at the median of the measurement errors, which are 45.5*m* without whispering and 32.5*m* with whispering, we see an improved positioning quality by about 29%. As we only did the measurements 2 times, our ability to make assumptions about the stability of the positioning method is limited. But looking at the mean values of the differences between the two measurements, which are 23.53*m* without whispering and 14.37*m*, the stability seems to have improved, too.

5 APPLICATION SCENARIO

Many indoor navigation and guidance applications suffer on high positioning costs and on low positioning 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 (less than twenty-five meters) navigation and positioning applications could be deployed and used. In Fig. 9 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, traveling 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. 9 shows a travel chain element with the travel mode walking. A traveler is guided with the help of discrete position points mapped to his planned route to the right gate, e.g to take his plane.

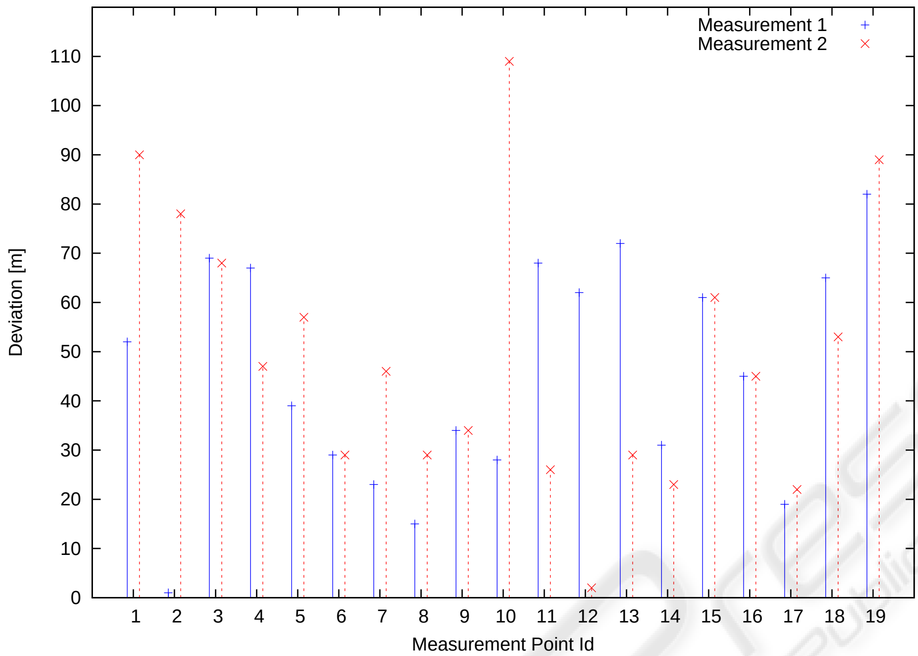

Figure 7: Deviation of the measured positions without usage of the whispering approach.

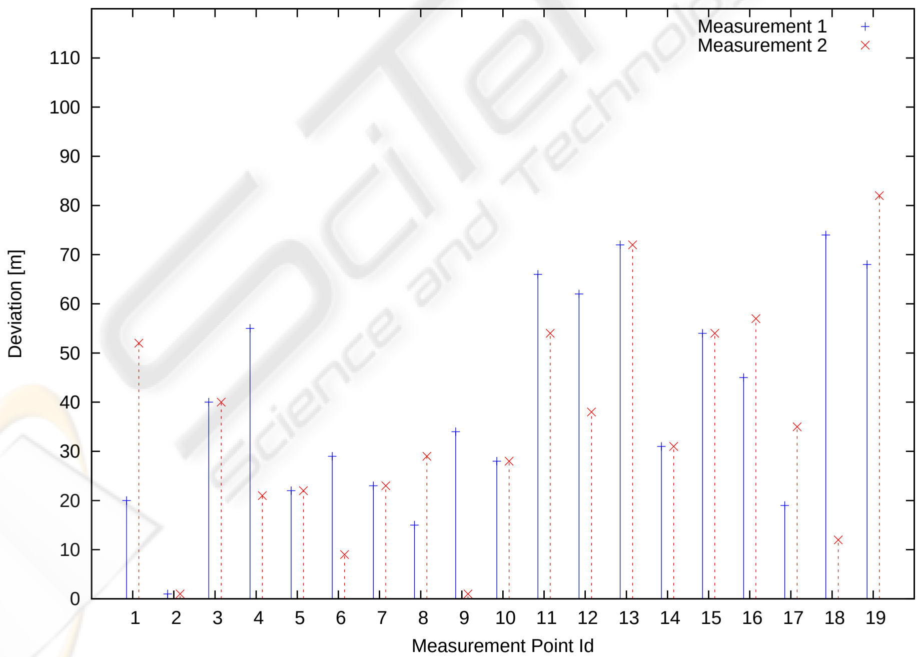

Figure 8: Deviation of the measured positions using the whispering approach.

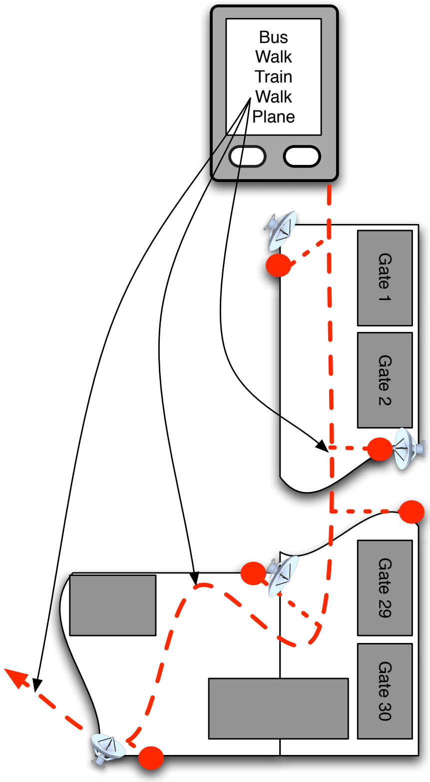

Figure 9: Application Scenario.

6 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 Internet connection, and it is applicable indoor and outdoor. The positioning accuracy is determined by the number of access points which can be *seen* by a mobile device, their radio range and how fine the sending power of the WLAN radio of the device itself can be adjusted. We could show on the Köln-Bonn airport that the approach gives better results than WLAN positioning without whispering. A limiting factor is the hardware's and driver's capability to reduce the sending power. Current systems are able to reduce the sending power to minimum of $1mW$. But to improve the positioning results further a adjustable sending power between $10\mu W$ and $1000\mu W$ is required. So, one future step is to modify the WLAN hardware to support this low sending power levels. Another approach can be to combine this approach with other positioning systems, as for example GPS, to a hybrid positioning system and expand the 802.11 standard to support context information for access points.

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