Indoor Positioning with a WLAN Access Point List on a Mobile Device

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***Abstract*—This paper presents indoor positioning results based on the 802.11 WiFi system (WLAN). It uses the existing infrastructure of buildings and the available technologies in personal mobile devices to calculate an indoor position consisting of floor and building section. A list of known WLAN access points and their location is the only requirement of this simple positioning algorithm. This approach is cheap, does not require calibration work and gives a position resolution in the form of building section and floor. These features make this work novel compared to known approaches. The results of the position calculations reveal an accuracy of 88% even in tricky building layouts. Real life position calculations during a person's work day showed as well good results. The signal strength measurements give reasons to conduct further research to achieve a sub building section resolution. Integrating other mobile device data, like calendar items Bluetooth scan results and data from different kinds of sensors, promises to further enhance the accuracy of indoor positioning and is the subject of further research in our laboratory.**

***Keywords*— access point, indoor positioning, mobile device, WLAN.**

I. Introduction

THE knowledge of a person's position[1] is a valuable piece of context information on which other applications or services [2] are based. The position can be gained by various means depending on the method of position detection and the environment, e.g. is the person indoors or outdoors. Automated position calculation methods with little or no calibration work are the aim for large scale positioning implementations. The user's personal mobile device, e.g. a smart phone, has in many aspects the qualities to fulfill this task of continuous position detection.

When it comes to position detection the Global Positioning System (GPS) performs well in locations that have a line of sight to the sky. But indoor positioning and urban canyons cannot rely on accurate GPS information. Additionally, indoor positions require information about the third dimension, in the form of floor.

Commercial indoor positioning and tracking systems, like Ekahau [3] and Geodan [4], require sophisticated and expensive hardware (e.g. radio tags), on the objects whose position is determined, and in the environment in which the objects are positioned. A position accuracy of one to three meters is achieved with these systems. But large scale implementation (ideally in all public buildings and offices) is not feasible due to the extensive costs and the need to equip the objects with additional hardware.

An indoor positioning approach on existing infrastructure in a building is made by RADAR [5]. A reported median resolution of 2 to 3 meters is achieved by signal strength measurements of WLAN access points. This approach requires a detailed radio fingerprint of the indoor area.

The Place Lab project [6] [7] [8] utilizes, among others, WLAN access points to calculate a position. The calculation is based on a list of known access points and their location. These access points and their estimated position are collected and updated by a user community (wardriving). These users submit their access points to a public database where other users can download them. The accuracy of the resulting position calculation depends on the quantity and quality of the known access points. The special requirements for indoor positioning, increased accuracy and third dimension, are not specially addressed in the Place Lab approach.

My work focuses on a simple and robust indoor positioning algorithm implemented in a mobile device using existing infrastructure and technologies based on the 802.11 WiFi system (WLAN). These features enable a low cost and low work effort solution for indoor positioning in large scale implementations. The achieved accuracy is limited, but still seen as valuable for certain location dependent services and applications.

The position calculation is based on a list of known WLAN access points and their location in the building.

[1] The term position is normally used to express the capability of locating the physical position of an object in a pre-determined space [1].

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WLAN scans detect these access points and an algorithm calculates the user's position with a resolution of building section and floor.

In office or public buildings often detailed maps or lists of WLAN access points exist for maintenance and operational use. This data is used in my approach to calculate the location inside a building without the need for wardriving or radio signal calibration measurements. The list can simply be distributed to mobile devices using internet or dedicated services.

The gathered results of practical WLAN scanning and position calculations on a mobile device demonstrated a good performance. The indoor position was expressed as building section and floor and was in 88% of the calculations correct despite a tricky building layout. Signal strength measurements give reason to believe that a sub building section resolution is possible.

Using other available data of a personal mobile device to calculate a user's current position more reliably or more precisely will be part of further research. Calendar entries, Bluetooth scans, and sensor data, like acceleration (motion), magnetic field (compass), and atmospheric pressure, will for example be used.

II. Materials and Methods

A. Hardware

The Nokia 770 Internet tablet [9] was selected for the first implementation and testing of the indoor positioning algorithm. The tablet is equipped with a WLAN and Bluetooth radio, has a touch screen and a compact size of 141 mm × 79 mm × 19 mm. The well documented Linux platform and the available development software was the main reason to select this mobile device in this work.

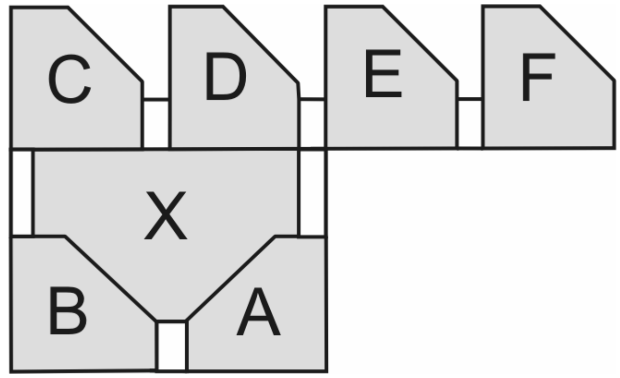

Fig. 2. Building layout with six wings (A to F). Each of the seven floors exhibits this six wing layout. The area marked with X is a light well (open space) extending through all floors.

The tablet was updated with the newest operation firmware of Maemo 2.0 [10]. Bugs had been fixed and new features, partly necessary for the indoor positioning, had been introduced in this version.

For using low level WLAN functions, an open source wireless tools library was in addition installed on the tablet. This library provided functions for scanning WLAN access points and activating and deactivating the WLAN radio. A better control of the tablet's operation was insured by this library than using the platform's own WLAN related functions.

B. Positioning Algorithm

The position calculation algorithm is based on using a list of known WLAN access points that are installed in the building. This WLAN list holds the mac addresses

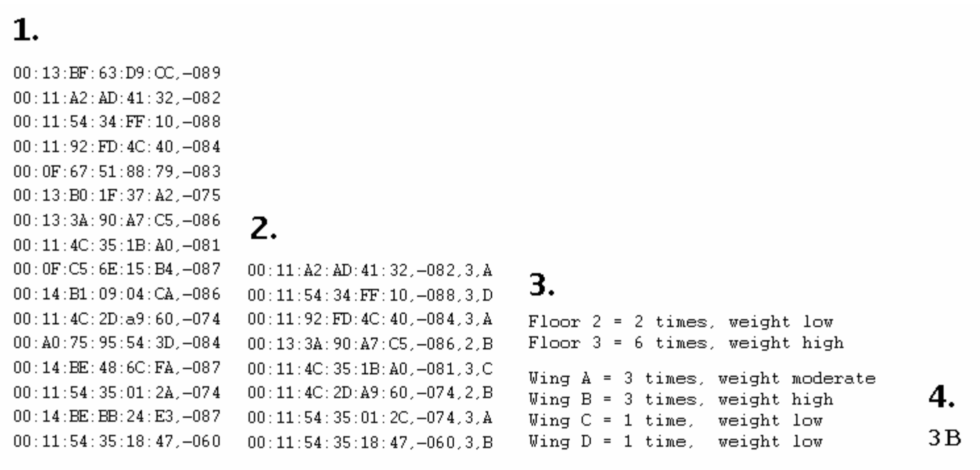

Fig. 1. Illustration of the position calculation algorithm with example scan data. In column 1 all detected WLAN access points are listed with their corresponding received signal strength (rss) values. In the 2. column only the building's access points and their locations are listed. A counting and weighting is done in the 3. column (e.g. 6 times was the floor 3 detected, and the rss values result in a high weight for this floor). The calculated position is then indicated in 4.

TABLE I
SUMMARY OF POSITION CALCULATIONS AT DEFINED LOCATIONS

Description	Quantity
Total number of position calculations	65
Position calculations at ambiguous locations (e.g. on platforms or in hallways between wings)	8
Correct position calculations	50
Wrong position calculations	7
Wrong position calculations at positions near the inner open space	4

of the building's access points and their locations in form of building section—here wing—and floor.

The emphasis in the first approach was laid on simplicity of the algorithm. Therefore only the scan result of one scan is used to calculate a position. A scan also provides the receive signal strength (rss) of each found access point. This information was also integrated in the position calculation.

Four steps lead to a position calculation: (1) WLAN scan, (2) identifying the WLAN access points of the building's WLAN list, (3) counting and weighting the detected access points of the floors and wings, (4) identifying the most detected and highest weighted floor and wing, which represent the calculated position. The weighting of the detected building sections and floors is based on the receive signal strength values. Fig. 1 illustrates these four steps on an example scan.

C. Data Collection Setup

The results presented in this paper are based on data collected in one building. The building has seven floors of which the first floor is on ground level. The basement floors were not considered because no WLAN access points are installed there.

Fig. 2 shows the floor plan of the building. There are six wings and a light well extending through all the floors above ground level. In each wing on each floor two WLAN access points are located which are documented in the WLAN list. The only exception is the cafeteria area located in wing C and D on the first floor, here no access points are situated.

The light well, marked with X, is an open interior space. Here only on the ground floor two access points are located. In total 82 access points are distributed in this building.

In this indoor environment three different sets of data were collected.

1) Documented walk through the building: To evaluate the performance of the position calculation algorithm I selected 65 locations inside the building. On a map I marked each scan location. At each location I initiated manually a WLAN scan. The scan data and the calculated position were stored in two separate files.

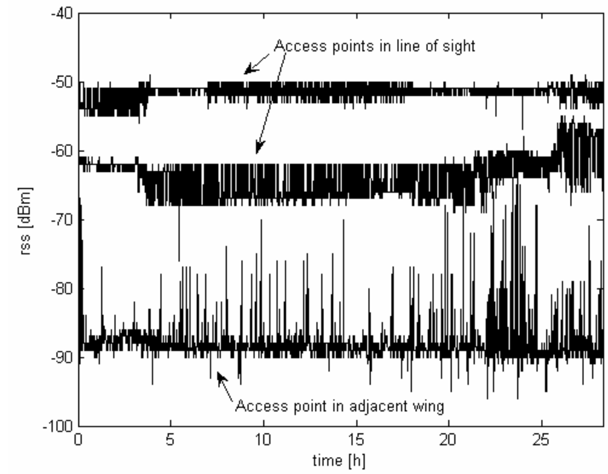

Fig. 3. Receive signal strength (rss) of two in line of sight access points and one access point in an adjacent wing during a stationary WLAN measurement.

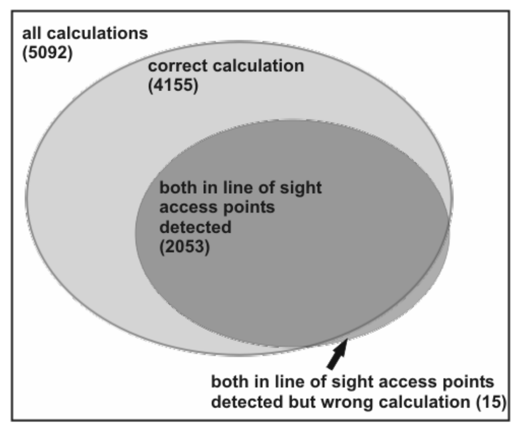

Fig. 4. Venn diagram of the stationary data collection with respect to the detection of the "in line of sight" access points.

2) Continuous WLAN scans at one location: To evaluate the WLAN scanning performance I placed the WLAN scanning device at one location in the center of a wing. Both WLAN access points of this wing, which are in the WLAN list, were in line of sight and only a couple of meters away.

The device performed a WLAN scan every 20 seconds and saved the scan data and the calculated position into two separate files. This data was collected over a time period of about 28 hours.

3) Real life data collection: The WLAN scanning and position calculating tablet was on a person during an ordinary work day in the building. The tablet performed every 20 seconds a WLAN scan and calculated the position. The calculated position was also displayed on the device. Again the scan data and the calculated position was saved into two separate files on the device.

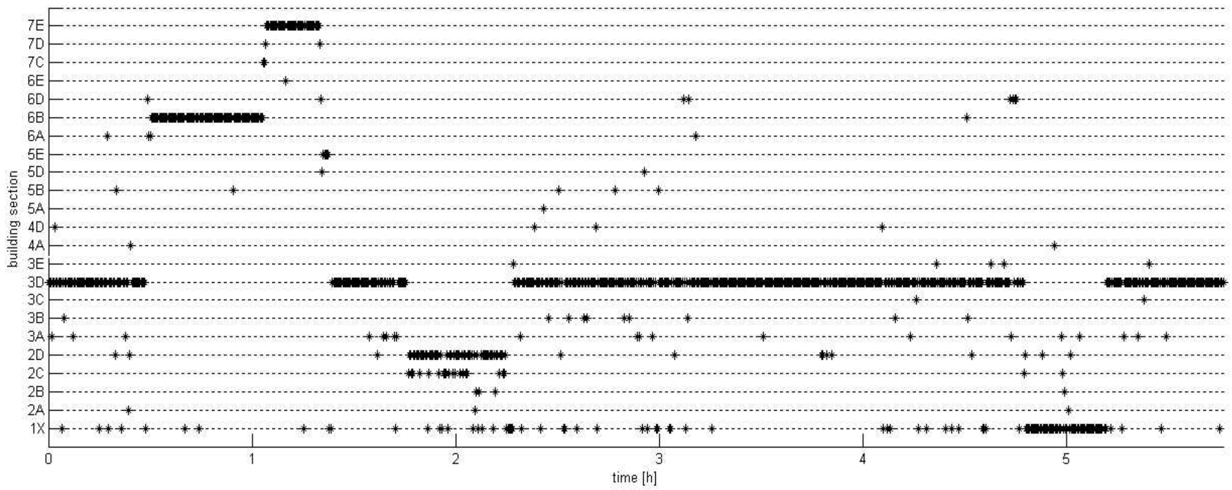

Fig. 5. Real life data collection and position calculation during a person's work day in the office building.

III. Results

In three data collection setups an indoor position was calculated based on WLAN scans and a WLAN access point list. The measurements were carried out with a Nokia 770 internet tablet inside an office building.

In the first setup 65 WLAN scans and position calculations were performed at defined and documented locations throughout the whole building. The calculated position was stated as building section (here wing) and floor.

Table 1 summarizes the accuracy of the position calculations. If the calculations at the ambiguous positions were excluded, the overall accuracy would be 88%.

Collecting stationary WLAN scan and position data was done in the second setup. During a period of 28 hours the tablet scanned and calculated with a time interval of 20 seconds at a fixed location at the center of one wing. The detected signal strength of two nearby (in line of sight) WLAN access points and one further away access point (adjacent wing) are plotted over the measurement time in Fig. 3.

The collected data in this setup revealed that both "in line of sight" access points were only detected in 40% of the scans. The resulting position calculation accuracy of the total 5092 measurements was 82%.

The Venn diagram in Fig. 4 points out the above found results. It also indicates that a position accuracy of 99% could have been achieved if both "in line of sight" access points would have been detected as they should have.

A real life data collection was undertaken in the third setup. The tablet was carried on a person during one work day in the office building. WLAN scans and position calculations were executed every 20 seconds.

The plot of the calculated location over the measurement time is shown in Fig. 5. It indicates clearly the positions of the person in the building. Wrong position calculations are readily seen.

IV. Conclusion

The data collected in the first setup (documented locations) and third setup (real life) reveal a good performance of the implemented simple indoor positioning algorithm. Especially the real life positioning results give confidence of improving the position accuracy by considering a series of WLAN scans for the position calculation. This way faulty position jumps over several floors or wings can be detected and corrected.

In Table 1 the problem with the light well is reflected. Most of the wrong position calculations are based on the special layout of the building with its open inner space. WLAN access points from other wings and floors are highly visible near the light well, which results in an increased number of false position calculations at locations close to the light well.

On the other hand the position calculation algorithm is very reliable in the non open inner space parts of the building. The regular distribution of the WLAN access points—two access points in each wing on each floor—is supporting these good results. An evaluation of the algorithm's performance in other buildings with different layout is still required and planned.

The stationary data collection results, see Fig. 4, show that the WLAN scanning procedure needs improvement so that the nearest (in line of sight) access points are reliably detected. A passive WLAN scanning, identical to the Placelab's implementation, detects only in 40% of the scans the nearest and "in line of sight" access points.

Additionally the receive signal strength results of the stationary data collection setup shown in Fig. 3 justify implementing and testing a simple triangulation approach. Hence a sub wing resolution of the position calculation could be achieved.

Other improvements and evolutions of the described indoor positioning algorithm include the integration of Bluetooth scan results, usage of motion, compass or pressure sensor data and other context related information, e.g. calendar entries, photos. At last solutions must be found which enable an (automated) access or distribution of the building's WLAN access point lists. User friendly updates and additions to the WLAN access point lists, which are stored on the mobile device, have to be considered as well.

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