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User Positioning System for Mobile Devices

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Abstract. **In the recent years, the Global Positioning System (GPS) has become a standard for the location and navigation for a huge number of people all over the world. This system is unquestionably one of the most significant developments of the twentieth century. GPS employs a great variety of applications from car navigation and cellular phone emergency positioning even to aeronautic positioning. Despite the fact that it plays an essential role in today's world, GPS has some limitations. The main disadvantage is the inability to operate inside the buildings because of the loss of signal from the satellites. During the last decade, the interest in location based services has significantly increased. It is related to the existence of ubiquitous computers and context awareness of mobile devices. Information about the position plays the great role in the field of security, logistics and convenience nowadays. Thus, it is necessary to fill the gap at the point where Global Positioning System does not perform satisfactorily.**

I. Introduction

THE idea is to design the system complementary to GPS which would be able to determine the location in the places where GPS is not. It is possible to use a wireless LAN system and its existing infrastructure to find the users location indoors. The wireless communication system was designed to provide users with a possibility to move around and still be connected to the local network or be able to use Internet access without cables. Nevertheless, it is possible to use some of the properties of wireless communication to determine the location. Analyzing the transmitted signal, a mobile device can estimate the distance between the access point and the terminal itself. Then, by combining the measurements from more than one access points, the mobile device can determine the exact location of the terminal.

II. WLAN Positioning Principle

In recent years, the WLAN IEEE 802.11g standard has gained high popularity; the number of devices using wireless networks is still constantly increasing. Nowadays, WLAN infrastructure is maintained nearly everywhere where people appear frequently. This enables customers to connect to the Internet in public places such as airports, hospitals, universities, or shopping malls. The majority of modern mobile devices is equipped with a WLAN interface and that enables them to connect to wireless access points. In recent years, the position information as well as the WLAN standard IEEE 802.11g have become very common. This motivates developers to produce systems based on WLAN networks which are able to determine a user's location.

To estimate the real-time location of a user, location systems have to perform a number of steps and various calculations [1],[3]. The estimation of the distance from the access point is the first phase needed to determine the exact location. It is the method of calculating the radius of a circle in two dimensional spaces or a sphere in three dimensional systems. The calculation of more than one distance from several Access Points (APs) could be used to estimate the exact location [2]. A location could be described as a set of coordinates pointing at a particular position in a space or on a map. The majority of the positioning applications require that the position of the user's device be estimated with a good accuracy, but sometimes another criterion, such as no complexity or low costs, is more important. Positioning systems based on wireless networks use the properties of the access to a medium. They use various physical attributes to measure the distance between two terminals [4-5].

The main principle states that signal strength at the receiver is inversely proportional to the square of the distance that the signal travels. Based on that rule and the characteristics of a wireless signal in a researched environment, the distance between two terminals can be determined. In comparison to methods that are based on the time of flight technique, the Received Signal Strength (RSS) approach has a number of advantages. To apply the RSS method, no hardware changes are usually required. This method can be implemented in a customary wireless communication system such as the IEEE 802.11g standard with the facility to read a received signal strength indicator. The special synchronization and timing techniques are not relevant. Owing to the low costs of implementation and the simplicity, the RSS approach has a great chance to become the most popular technique used for indoor positioning systems. Nevertheless, there are some restrictions of the RSS location technique. The electromagnetic signal is very prone to interferences and the effect of multipath propagation. A position awareness system based on RSS method must use a specific database or increase a number of static base stations to achieve higher accuracy [6][8].

The RSS fingerprinting approach is based on sampling and recording of characteristic patterns of a radio signal in a specific environment and is called pattern recognition or fingerprinting. The location patterning technique is implemented in the software entirely. This reduces the complexity as well as the cost of performance and, at the same time, guarantees high positioning precision. However, a special database must be created for every single area and every change which effects radio propagation requires the re-creation of the whole database[7],[9].

The deployment of a location system based on the position patterning has two measurement phases. The first one, which is called the offline or the calibration phase, results in the creation of the database. The second phase, called the online or operational phase, takes place when the real time signal strength values are matched with the previously constructed database components associated with the reference points.

III. Project Implementation

The created WLAN Positioning applies the position determining approach based on the received signal strength and access point information from the 802.11g wireless network. Tests were conducted in a three-storey building with the overall surface area of about 250 square meters using three access points which were distributed all over the building, each on a different floor.

The client-based approach is applied in the system that includes the offline phase as well as the online phase. The developed application could operate in both modes. The first one is a calibration mode and includes the construction of a radio map of an indoor area containing measurements of the received signal strength from access points in each reference point.

The localization system uses three access points that provide overlapping coverage area, with the strongest signal power in the calibrated arena. Another wireless networks detected by the system are not used by the application because they do not guarantee the sufficient coverage and the high enough signal strength value. The second mode of application is the operational mode and this mode includes the determination of position in real time. In this phase, the application receives a signal from fixed access points and performs the calculations on signal strength to obtain the current position of the device. The approach used to determine the device position is the nearest neighbor method based on the Euclidean distance.

The designed positioning system operates on mobile devices in conjunction with the 802.11g standard wireless access points. The calibration and the operational phase were conducted using already installed access points in the three storey building. The coverage region includes three floors with the surface area of about 250m2. This place consists of 15 different locations where 55 reference points were defined. The plan of each floor with the position of the reference points is presented in Fig 1.

The User Positioning System is a software-based project developed to work on the Sony Ericsson Xperia mobile device. The mobile phone operates using Android 2.1 and is equipped with WLAN card working with 802.11g technology.

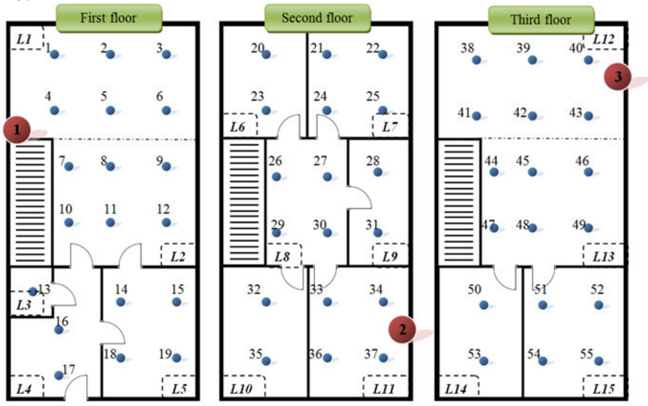

Fig. 1 Plan of the building with tagged reference points.

Due to the fact that the project was designed to work on the mobile phone Sony Xperia, there were some specific hardware restrictions. The system uses the embedded wireless network card and its ability to deliver the received signal strength values. The positioning approach could be chosen from the set of methods that use the RSS approach to determine the location. The approach based on the angle or time of arrival may not operate on available mobile device. (In order to measure the angle, it is necessary to use a directional antenna or an antenna array, where each antenna is tuned to a different optimum frequency. Unfortunately, it is not possible to use this method on a mobile phone, which uses an antenna with properties similar to these of omnidirectional antennas. No possibility of tuning the frequency of the antenna makes it also impossible to construct a suitable antenna array).

Due to the fact that the system was created to operate in a very complex environment where the propagated signal was prone to various distortions caused by multipath phenomena, the propagation model method could not be applied in the described system. The approach which could give the satisfactory results in that complex environment and which was applied in the project was the received signal strength fingerprinting approach that is based on the nearest neighbor algorithm.

The User Positioning System could operate in two modes. The first mode uses the offline phase which contains a collection of reference points, what results in the creation of the database. This phase is performed before the real-time operational phase and provides references for the localization algorithms used in the actual position localization. The constructed database consists of reference points at a specific location and three median values of RSS that correspond to the fixed access points. The main database is associated with the described environment – the three-storey building. This database is used in the real-time operational mode as a reference databank for the application to find the most accurate position of the device.

The second mode of the program is called the positioning phase. In that mode the application matches real time measurements with the database that was already created in the previous phase. The mobile application in the positioning mode measures the real time RSS values from three access points. Due to hardware limitations, the program could obtain only one sample per two seconds. During this phase, the analysis including a number of sample values resulting from the calibration process was compared with the systems accuracy. The application depending on user preferences could operate in three different modes that vary in the number of samples. The first one uses instantaneous measurements of the RSS value to determine the best reference point, while the other two use three and nine samples to localize the device. The corresponding time of the calibration is two, six, and eighteen seconds. The received RSS values from more than one sample are translated into their analogue median values in order to create a single vector of signal strength values.

The constructed real time vector of measurements is compared with the already created database, using the nearest neighbor algorithm which was already described in detail in the previous section. Each value of received signal strength in the vector is compared with the corresponding values with each reference point from the database, using Euclidean distance. The reference point with the smallest distance is considered the best position by the program. The application displays the determined position at the screen.

IV. Test Measurements

The tests of the project were carried out with various parameters. The actual accuracy of the system varies in the number of samples obtained in real time measurements. The results presented below are divided into three parts as three different approaches have been considered.

The first part includes only real time RSS values from all access points. This leads to a very quick determination of the position; however, this approach cannot provide the efficient accuracy. The next approach compromises on the time of calculations and the accuracy and uses the measurements of three samples which require six seconds for locating the position. The last approach uses measurements of nine samples which give the best accuracy; however, this method takes eighteen seconds to determine the current position.

The first approach, which measures one instantaneous RSS value, does not provide the satisfactory accuracy (Fig 3.). The analyses have shown that only in 17% of the tested positions the location was determined correctly. Only in 36% of the cases, the position was estimated correctly as being located within a room.

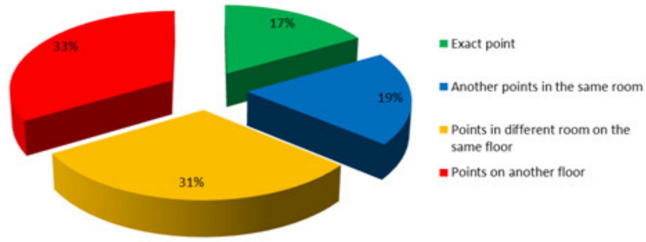

Fig. 3 Accuracy for the single sample approach.

The second approach, which measures three instantaneous RSS values, provides better accuracy (Fig 4). The analyses have shown that in 32% of the tested positions the location was determined correctly and in 53% of cases the position was estimated correctly as being located within a room.

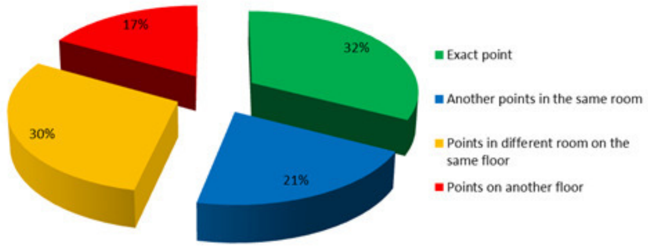

Fig. 4 Accuracy for the 3 samples approach.

The last approach, which measures nine instantaneous RSS values, provides the best accuracy. The analyses have shown that in 48% of the tested positions the location was determined correctly and in 81% of cases the position was estimated correctly as being located within a room.

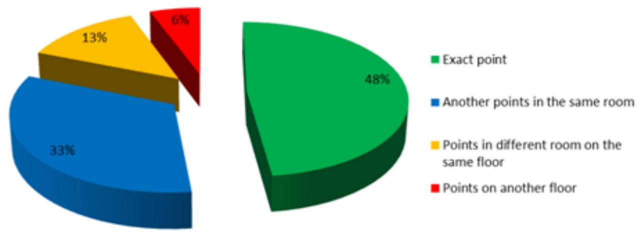

Fig. 5 Accuracy for the 9 samples approach.

V. Conclusions and Future Work

The system tests were performed with three different approaches. They vary in the amount of samples in real time measurements, what results in the difference of position estimation time as well.

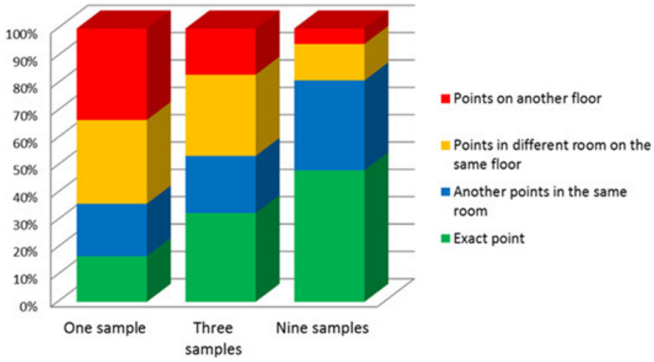

Fig. 4 The comparison of the system performance for the three approaches.

Undoubtedly, the approach that measures 9 samples provides the best accuracy. However, 18 seconds to obtain the position is too long (during this time the real positioning can change). The compromise might be the three samples approach that has the satisfactory accuracy and does not take too long to calculate the location.

The goal of the project was to design the positioning system for mobile devices that would perform satisfactorily in an environment where the Global Positioning System could not operate effectively. The project was successfully implemented using the already existing infrastructure of WLAN networks in a three-storey building. The most suitable approach for WLAN positioning was chosen after a careful literature review. The method implemented in the localization system is the RSS fingerprinting technique based on the nearest neighbor algorithm.

The User Positioning System for Mobile Devices that works on mobile phones with the Android operating system has been successfully implemented. The designed application could work in two modes. The program working in the first mode constructs the database with access points and RSS values corresponding to them. The result of the calibration mode is the database that is a reference map for the operational mode. The second mode operates in the localization mode and compares real time measurements with the database in order to point the current position. The system has been tested in a three-storey building and has achieved the accuracy of about 80% for the localization within 20 seconds with the accuracy to one area of one room (about 15 square meters). The User Positioning System belongs to a minor group of applications which were developed to operate on mobile devices. The implemented system is not expensive and it can become very popular for handheld indoor positioning because nowadays a lot of people have Android mobile phones and the wireless local area networks are becoming more and more common.

Nevertheless, the system implementation could be improved in some steps in order to increase accuracy and effectiveness. Firstly, the accuracy could be improved by implementing more access points in the building. The number of access points will not prolong the time of calibration dramatically but the higher number of access points is, the better quality of signal strength is and, as a result, the better accuracy of the system is. Moreover, the implemented system is not resistant to environmental changes. Each little change in an environment such people moving, doors closing or opening or even furniture moving could dramatically increase the position inaccuracy. The solution could be the creation of a flexible database that would be able to adapt to environmental changes.

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