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ALTERNATIVE ACCURATE VEHICULAR POSITIONING SOLUTION IN INTELLIGENT TRANSPORT SYSTEMS

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Abstract: *A vehicular positioning is generally based on Global Navigation Satellite Systems (GNSS). The GNSSs have obvious advantages, but these systems have big problems in density urban environment, tunnels and buildings (e.g. parking houses). Alternative positioning systems should be implemented in these critical environments. For this purpose can be used various wireless communication platforms, e.g. cellular, ad hoc networks or RFID (Radio Frequency Identification).*

This paper presents overview of useful localization methods based on received signal strength. Their possible implementation in transport systems by means of mentioned platforms and their results.

Key words: *vehicular positioning, fingerprinting method, RSS based positioning, intelligent transport system.*

INTRODUCTION

Mobile positioning is a broad topic that has received considerable attention from the research community over the past few decades. There is increasing interest towards positioning technologies and Location Based Services (LBS), but the utilization of mobile positioning in emergency situations and LBS are not alone. Mobile positioning plays an important role also in transport systems. The vehicular localization in transport is very actual issue. There can be used various wireless networks for vehicle position estimation. The GPS (Global Positioning System) is mostly utilized positioning system in transport, but the paper is focused on alternative positioning systems.

Alternative positioning systems can be based on various platforms (cellular, ad hoc networks etc.). The cellular networks are widely used for communication. Therefore, their utilization for vehicular positioning is possible. Application of ad hoc networks is not only in security services but also in location based applications.

Ability to define position of vehicle depends on accurate positioning data achieving. This information is used to calculate the vehicle position. In this case, a vehicle is called mobile device. The data capturing is realized by measuring particular parameters of the radio signal. Measurements relate either explicitly or implicitly the mobile device position to the position of reference devices or to the specific behavior of the mobile device and its surrounding environment. The mobile device position can be calculated by means of the measured data.

Mobility of the mobile devices is high and there is usually no restriction regarding the mobile device environment. It is necessary to differentiate indoor and outdoor positioning environment and to choose correct positioning technology. This is very important especially in transport systems. At the present time, a lot of parking houses is used and there is not possible to utilize GNSS. Hence, alternative solution has to be used.

The most accurate positioning results can be obtained by means of GNSS based positioning, but this system is applicable only in outdoor environment. Indoor environment requires the different positioning technologies, e.g. cellular, ad hoc, sensor or RFID positioning.

Generally, we can say that the application of positioning system needs to take into consideration two basic factors: the positioning accuracy and deployment costs. These factors may be opposite, but they are important for successful positioning based solution.

POSITIONING IN WIRELESS NETWORKS

The concept of positioning is not limited just to the geographic representation of physical location with sets of coordinates (latitude, longitude, and altitude). It is also applicable to symbolic location in a non-geographic sense, such as location in time or in a virtual information space, such as a data structure or the graph of a network.

Common to all notions of location is the concept that the individual locations are all relative to each other, meaning that they depend on a predefined frame of reference. This leads to a differentiation of the relative and absolute positioning [1].

Usually, $[x; y; z]$ coordinates in a Cartesian reference coordinate system by themselves are not meaningful for context-aware system services and the other information needs to be associated with this position information. If a time dimension is introduced, we are able to specify where and when a certain event took place resulting in sets of $[x; y; z; t]$ for each position information.

Positioning Methods Classification

There are numerous methods that can be considered for implementation in wireless position location systems. It is possible to define many criterions for separation of the particular methods.

Main classification of positioning methods is possible on the basis of measured parameter used for positioning:

- ♦Cell identification.
- ♦Received signal strength based methods.
- ♦Time based methods.
- ♦Angle of arrival based methods.

The reference device represents Base Station (BS) or Access Point (AP) and mobile device or vehicle represents Mobile Station (MS).

RSS based methods applicable to Intelligent Transport Systems (ITS) are described here in detail, because of their simple implementation. The main reason to use these methods is that no additional hardware is required for its implementation to existing networks. A lot of methods are not applicable due to their expensive initial costs. Time and angle of arrival based methods belong to this group. Received signal strength based methods are described here

RECEIVED SIGNAL STRENGTH BASED METHODS

Received Signal Strength (RSS) based methods are one of the oldest positioning methods. Generally, there two possible realizations based on received signal strength:

- ♦circle triangulation,
- ♦fingerprinting method.

RSS based on circle triangulation

Transmitted signal between transmitting BS and receiving MS is attenuated and this phenomenon is utilized by means of RSS method. RSS measurement can be realized either at the MS (measuring the signals propagating from several BSs) or at the several BSs (measuring the signal strength of the MS). The received signal level (*RxLev*) measurements are then converted to distances between MS and particular BSs. Each *RxLev* measurement will provide a circle, centered at the corresponding BS. The distance between MS and BS represents circle radius i.e. MS lies on the circle. The MS location can be calculated by the intersection computation of circles of known radius by using a calculation algorithm. For 2D positioning it is necessary to use at least three BSs in order to resolve ambiguities arising from multiple crossings of the lines of position (see Fig. 1). More detail information can be seen in [2].

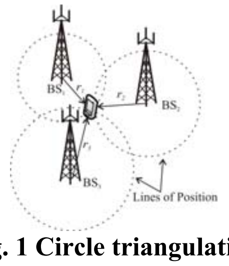

Fig. 1 Circle triangulation

Large number of mathematical models describes behavior of a signal propagating in a particular environment. Every kind of environment is described with a typical model e.g. open area, rural area, urban and suburban area, indoor area, etc. [3]. Positioning accuracy is increasing in case that the correct model is used.

Fingerprinting Method

The main problem of above mentioned method lies in the accuracy of estimation the distance between MS and BS. This phenomenon is mostly caused by negative radio channel propagation conditions (multipath propagation, delay spread...). The results of various authors show that the suitable way to suppress this effect is fingerprinting method. The collected signal characteristics are called *fingerprints*, due to similarity to the fingerprint comparison in forensics. In this case, the *RxLev* is signal characteristic.

Generally, process of this method can be divided into two main phases. The aim of the first phase (so-called offline phase) is to create radio map of the particular area. Radio map is the database of points with the strictly defined position. Every point has the various *RxLev* from several BSs. The entire area is covered by a grid of points (see Fig. 2). Every person has unique fingerprints and also every point from database contains unique combination of the signal characteristic from some BSs.

MS positioning is realized in the second phase (online phase). MS will create a sample measured vector of signal characteristics from different reference devices (BSs). This vector is compared with the information about every radio map point (fingerprint). The aim is to find fingerprint that is most similar to the measured vector. The most common algorithm used to estimate the location is Euclidean algorithm. It computes the Euclidean distance between the measured signal characteristics vector and each fingerprint in the database and then the coordinates associated with the fingerprint that provides the smallest Euclidean distance is returned as the estimate of the position.

The advantage of a fingerprinting positioning method is that it allows determining the location very accurately as all the signal propagation oddities can be taken into account. However, the more details are learned, the more vulnerable is this radio map to changes in the environment, such as construction of new buildings, weather conditions, moving furniture (indoor positioning) or even people and cars moving inside or outside the buildings. The important factor is that these characteristics are consistent in time, e.g. a medium-weak signal from a given source at a given location is likely to be similar tomorrow and next week.

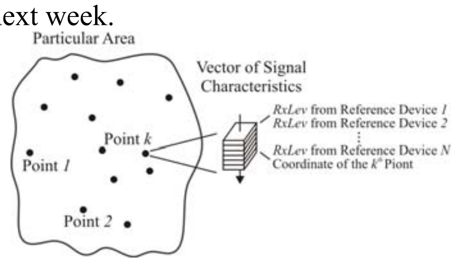

Fig. 2 Fingerprints from *RxLev*

Performance of the fingerprinting method with *RxLev* is better in areas with significant multipath propagation. Due to the big demanding effort during radio signal strength collection from the concerned area to realize a fingerprint database, predicted *RxLev* data of the area are rather used. For this reason is utilized a lot of predictive algorithms, e.g. [4].

Fingerprinting method can be used with different network platforms (e.g., cellular, 802.11), with different types of input data and for different environment (urban, rural or indoor).

Compared with most other location solutions, RSS positioning method does not require expensive base station equipment. There is faster deployment speed, and covers current and legacy MSs making it a low-cost solution for emerging location based services across the world.

In the following section, results obtained by means of fingerprinting method in two different environments are shown. The first experiment was realized in outdoor environment in cellular network (GSM). In the second case, it was realized in indoor environment and communication platform was IEEE 802.11b.

RESULTS AND INTERPRETATION

In the following part, we discuss results obtained in two different environments by means of above described algorithm. The results provide detailed analysis of positioning accuracy in terms of root mean square error (RMSE). The RMSE is calculated as follows:

$$(1) \quad RMSE = \sqrt{(x_s - x)^2 + (y_s - y)^2} \ [km].$$

Results for outdoor Environment

The first experiment in outdoor environment was realised in real GSM network in Zilina city centre. There is sufficient multipath environment with a lot of buildings and movable obstacles.

The measurements were realized by means of movable measuring station. This station consisted of GSM/GPS module and location server. The location server provided the communication and data collection from the modules. It also recorded measured data and computed estimation of MS position. The role of GSM part was measuring of signal strength *RxLev* and *BS Identification* from all available BSs. The maximum number of monitored cells can be seven, i.e., one serving cell and six neighbour cells in the same moment. GPS module was monitored current (precise) coordinates of MS position. The communication architecture of the measuring station, GPS and cellular network is shown in Fig. 3.

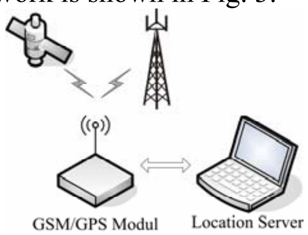

Fig. 3. Communication architecture

The measurements were done in three scenarios. The first scenario represents dense radio map, i.e. max. distance between measured points was 10 m. In the second case, the mentioned distance was 20 m. Finally, in the last scenario, the distance was max. 50 m. The impact of dense of points in radio map can be seen the following table [5].

Table1

Scenario	RMSE [km]	σ [km]
1	39.61	23.35
2	99.21	9.59
3	147.76	45.43

As can be seen from Table 1, the most precise results were obtained in the first case. It is obvious that it was caused only the density of the radio map, because the environment was same in all scenarios.

The achieved accuracy is poorer compare to typical GPS accuracy in this environment. Proposed positioning solution can not be used for application where small positioning error is requested. However, it can be used as backup solution. This position estimation can also serve for AGPS (Assisted Global Positioning System).

Results for indoor Environment

The indoor environment is represented by typical central Europe building (concrete-steel building). The signal propagation condition is absolutely different compare to outdoor environment especially in used unlicensed 2.4 GHz ISM band (Industrial, Scientific and Medical). The signal is attenuated by walls, doors, furniture and also persons.

In this case, GPS could not be used for estimation of reference position. Therefore, local coordinates system was created. Each point of radio map belongs to the coordinates system.

In this experimental setup, five AP were used as reference devices. Localized device was laptop equipped with wi-fi card. The location server was also installed in laptop. The laptop measured *RxLev* and *AP Identification* from all available APs and estimated own position based on data from database.

The size of observed area was 60 x 20 m. The signals from all APs were presented everywhere in the observed area.

The positioning accuracy was investigated for two different places: room and corridor. Propagation conditions are absolutely different in these places. The change of environment conditions has also impact on positioning accuracy. For example, the change of the environment conditions can be open or closed doors, move of furniture… The impact of this factor is investigated by means of open/closed doors during the measurements. The radio map was created when all doors were open. MS positioning was done in two cases: open and closed door. Finally, the impact of the number of APs used for MS positioning was also observed.

Fig. 4 depicts dependency of RMSE on given positioning place. More accurate results were achieved in the rooms compare with corridor. The difference has been approximately 0.5 m. During this experiment, the number of used APs = 5 and the density of the raster was 1 m.

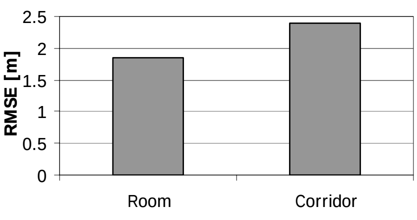

Fig. 4. RMSE vs. place in indoor environment

Fig. 5 shows the RMSE as a function of the open/closed doors. In this case, the measurements had done in rooms and also corridor. The number of used APs = 5 and the density of raster was 1 m. The more accurate results were obtained in the case of open doors. It is caused that radio map had been created under same environment conditions. It confirms fact, that change of the environment conditions has significant influence on the positioning accuracy.

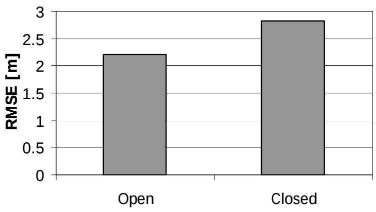

Fig. 5. RMSE vs. open/closed doors

The RMSE as a function of the number APs used for positioning is shown in Fig. 6. In this case, the measurements had done again in rooms and corridor. The density of raster was 1 m. The more accurate results were obtained for five APs. On the other hand, the biggest positioning error was obtained when two APs was used.

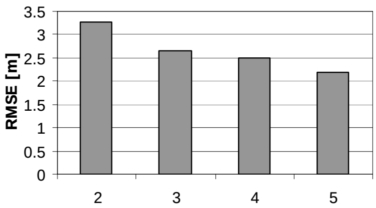

Fig. 6. RMSE vs. the number of APs used for positioning

Fig. 7 depicts dependency of RMSE on density of the raster. More accurate results were achieved with denser raster. The difference has been approximately 0.5 m.

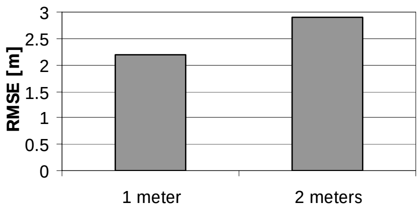

Fig. 7. RMSE vs. density of the raster

According to obtained results, we can say that accuracy achieved by fingerprinting positioning method is sufficient for some transport applications. It is clear that GPS accuracy is higher in outdoor environment. But implementation of these positioning solutions in booth environments is possible. They can be applicable especially for monitoring cars in underground parking. The application of 802.11 platform seems to be appropriate for this reason, because a lot of common devices is equipped with it.

CONCLUSION

We discussed and verified a simple and efficient fingerprinting positioning method using RSS measurements. The MS collects RSS data (*RxLev*) of the surrounding BSs or APs. The measured data were sent from MS to the localization server for position estimation.

The experiments were realized in indoor and outdoor environment, because of their absolutely different propagation conditions. Therefore, we can conclude that the performance of fingerprinting method was validated in the representative samples of environment.

The proposed positioning solutions for indoor and outdoor environment can be used as alternative positioning system for transport systems. The main area of its using is in road and partially railway transportation as supplementary or backup location based services. In ITSs, there are possible to use this method for monitoring of the number of cars in the specific area.

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REFERENCES:

[1] Tseng, Y. C., Huang, C. F., & Kuo, S. P. Positioning and Location Tracking in Wireless Sensor Networks. In M. Ilyas & I. Mahgoub (Eds.), *Handbook of sensor networks: compact wireless and wired sensing systems*. Florida, Boca Raton: CRC Press LLC, 2005.

[2] Willassen, S. Y. A method for implementing Mobile Station Location in GSM, 1998. Retrieved September 16, 2005, from http://www.willassen.no/msl/node1.html

[3] M. HATA, "Empirical Formula for Propagation Loss in Land Mobile Radio Services," *IEEE Transactions on Vehicular Technology*, vol. 29, no. 3, pp. 317–325, August 1980.

[4] Brunato, M., & Battiti, R. Statistical learning theory for location fingerprinting in wireless LANs. *Computer Networks and ISDN Systems*, 47(6), 825-845, 2005.

[5] Benikovský, J. Vytvorenie systému na určovanie polohy v reálnej sieti GSM. Diploma work, 2008. (in Slovak)

РЕШЕНИЕ ЗА АЛТЕРНАТИВНО ТОЧНО ТРАНСПОРТНО ПОЗИЦИОНИРАНЕ В ИНТЕЛИГЕНТНИТЕ ТРАНСПОРТНИ СИСТЕМИ

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РЕПУБЛИКА СЛОВАКИЯ

Резюме: *Транспортното позициониране се базира главно на Global Navigation Satellite Systems (GNSS). е GNSS системите имат очевидни предимства, но и големи проблеми в гъсто населената градска среда, тунелите и сградите (например в паркинг-сградите). В тези критични места трябва да се внедрят алтернативни позициониращи системи. За тази цел в на тези критични места могат да бъдат използвани различни безжични комуникационни платформи, например клетъчни, мрежи за специални цели или радиочестотно идентифициране (RFID – Radio Frequency Identification).*

Този доклад представя преглед на полезни методи за локализиране, основаващи се на силата на получените сигнали,възможното им приложение в транспортнитесистеми с помощта на споменатите платформи и техните резултати.

***Ключови думи*:** *транспортно позициониране, метод на пръстовите отпечатъци, позициониране, базирано на, интелигентна транспортна система.*