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# New Challenges for Intelligent Information and Database Systems

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# Indoor Positioning System Designed for User Adaptive Systems

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**Abstract.** The paper deals with the indoor positioning solution based on utilization of IEEE 802.11 network and fingerprinting method. This solution was designed as a part of user adaptive integrated positioning system that provides location-based services in indoor environment. The integrated positioning system is engineered for ubiquitous positioning, i.e. anywhere and anytime. The system for indoor environment is called WifiLOC and it is implemented as a mobile-assisted positioning system. The architecture and fundamental principles of the WifiLOC system are presented in this paper. The positioning system is based on the fingerprinting method, which utilizes signal strength information for position estimation.

**Keywords:** Fingerprinting localization, indoor positioning system, architecture, location based service, user adaptive system.

## 1 Introduction

The idea of User Adaptive System (UAS) lies in interaction between user and system through his mobile device. Such interaction can be linked with user's requests. These requests would include for example user current position or tracking information. The UAS also may take advantages of location based systems oriented to providing information support based on current user's position. Modern sophisticated services also deliver content to the user according its actual position [1] – [3]. On the other hand, success of the services consists also in performance of localization. Very attractive group of localization methods applicable in various wireless network platforms is called database correlation methods or fingerprinting. The implementation of the appropriate database plays very important role from effective function of the UAS. This paper designs a suitable indoor positioning solution for systems based on database correlation method. Various positioning systems based on wireless platforms were proposed in [4], [5]. But the more existing systems the more problems arise. Creation of new technologies is almost impossible because of many existing standards and limitations as well as exhausted resources e.g. frequency spectrum for radio waves. Also, entire design of new localization system would be very costly or otherwise complicated as well. Many producers therefore only attach existing systems (e.g. GPS - Global Positioning System) and do not attempt to improve them.

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The most popular algorithms used in indoor environment are based on IEEE 802.11 standard [6], [7]. Majority of these algorithms is based on RSS (Received Signal Strength) and fingerprinting algorithm.

Many researchers have paid an attention on the issue of mobile positioning using the received signal strength information [8] - [16]. This interest could be based on the fact that signal strength information can be simply measured by MS (Mobile Station) and does not need an expensive additional implementation costs compared with other methods.

The fingerprinting method seems to be more suitable for Non-Line-of-Sight (NLoS) environment compared to trilateration way and is also more immune against multipath. The main advantage is that it does not need to create new infrastructure, but it only needs to utilize information about existing surrounding networks.

We decided to base our solution on the IEEE 802.11 platform, because it is widespread. The basic idea results from the utilization of the platform apart from its main purpose, which is mainly to cover user data communication. Our approach adds a value to the IEEE 802.11 communication platform by providing user positioning. Furthermore, MS must not be modified and only localization server has to be added to the network. Only the software application for MS has to be implemented as a communication interface for a user and the localization server. Therefore, we decided to use Fingerprinting method based on received signal strength information in this work.

The rest of the paper is structured as follows. Section 2 introduces theoretical principles of fingerprinting method. In Section 3, implementation of the positioning system is presented. Section 4 concludes the paper and suggests some future studies.

## 2 Fingerprinting

Fingerprinting algorithm can be implemented in various ways from mathematical point of view. They can be divided into deterministic and probabilistic algorithms. In our work we deal with fingerprinting based on deterministic algorithm - Nearest Neighbor method (NN), which can achieve sufficient accuracy as well as more complicated method, when density of radio map is high enough [15].

Accuracy of this method in radio networks is according to [11] determined by two factors. Firstly, signal properties vary much at relatively small area. For instance, in few meters range, signal from an AP (Access Point) can get attenuated, get lost or be replaced with a stronger one. Secondly, these signals are relatively constant in time. It allows data gathering and their use in future.

A disadvantage of this method is sensitivity for environment changes such as object movement in the building (e.g. people, furniture), which altogether affect signal properties. It is necessary to update the map, but basically, walls and furniture affect the signal most of all and therefore update is not required so often.

Fingerprinting method consists of two phases. At first, it is creation of the radio map for an area where planned localization service is desired (see Fig. 1). Radio map is basically a database of spots with known position (coordinates) coupled with various radio signal properties, e.g. RSS, signal angles or propagation time. This phase is called off-line phase. Generally, the off-line phase can be performed by either measurements in a real environment or by prediction as described in [17]. In first case, it is very time consuming, but there are precise and real RSS information used in calculations. On the other hand, prediction of RSS is more comfortable, but the data is highly dependent on a quality of map model of given environment. There is a compromise between the demanding effort and accuracy in [12].

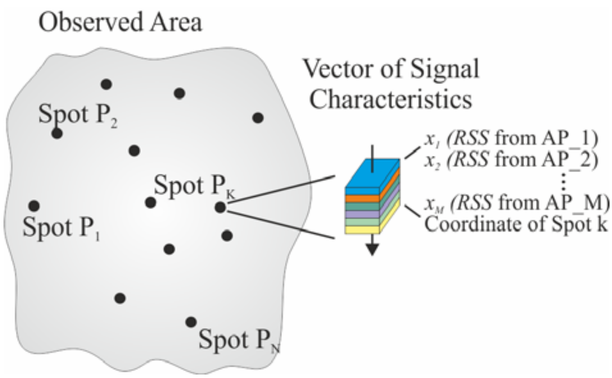


**Fig. 1.** Radio map for fingerprinting using RSS.

After the radio map is created, second phase can take place. MS measures signal properties at unknown spot. Then the radio map is searched to find a best match from existing spots. The match is actually the nearest point from database and is considered MS position (for NN method). This step is called on-line phase. Next sections deal with fingerprinting in more details.

### 2.1 Localization Algorithm

The most common method how to find the best match and actually perform localization is Euclidean algorithm. Let's assume a fingerprint in radio map, which is characterized by vector **P**:

$$\mathbf{P} = [x_j] = [x_1, \ldots, x_M], \tag{1}$$

where $x_j$ characterizes the spot, i.e. values of the signal properties (e.g. RSS). $M$ represents number of signal properties used for radio map creation. In general, let's consider the radio map contains fingerprints of $N$ spots.

$$\mathbf{P}_i = [x_{ij}] = [x_{i1}, \ldots, x_{iM}],\ i = 1, \ldots, N\ . \tag{2}$$

Unique identifiers of neighbor AP are stored in radio map as well as spot coordinates and they are coupled with $x_i$, but are not shown here for model simplicity. The whole radio map contains all fingerprints $\mathbf{P_i}$ and creates the set **S** written as

$$\mathbf{S} = \{\mathbf{P_i} : i = 1 \ldots N\}. \tag{3}$$

In case of MS localization, the signal properties are measured at unknown spot, a new fingerprint **Q** is obtained

$$\mathbf{Q} = [y_j]\,,\;\; j = 1,\ldots,M\;. \tag{4}$$

The Euclidean distance $d_k$ between vectors $\mathbf{P_k}$ and $\mathbf{Q}$ is defined as

$$d_k = \left|\mathbf{P}_k - \mathbf{Q}\right| = \sqrt{\sum_{j=1}^{M}\left(x_{kj} - y_j\right)^2}\;. \tag{5}$$

When Euclidean distance formula is applied on entire radio map, the vector of distances $\mathbf{D}$ is obtained between all radio map vectors $\mathbf{P}_\mathrm{i}$ and vector $\mathbf{Q}$ can be calculated as

$$\mathbf{D} = [d_i] = \left[\left|\mathbf{P}_i - \mathbf{Q}\right|\right] = \left[\sqrt{\sum_{j=1}^{M}\left(x_{ij} - y_j\right)^2}\right],\; i = 1,\ldots,N\;. \tag{6}$$

The element of vector D with minimum value defines the nearest spot to Q. Its position is recorded within radio map and its coordinates are considered the location estimate.

## 3 WifiLOC Positioning System

The basic properties of the WifiLOC are described in this part. The system utilizes signal information for positioning from surrounding Wifi networks. The system is based on fingerprinting positioning method and signal strength information as mentioned above.

### 3.1 WifiLOC Architecture

We decided to design WifiLOC as the mobile-assisted positioning concept. The mobile-assisted positioning means that the necessary measurements are done in a localized mobile station and measured results are forwarded to the network part LCS (localization server). The position is estimated (calculated) at server side. The architecture of the system is depicted in Fig. 2.

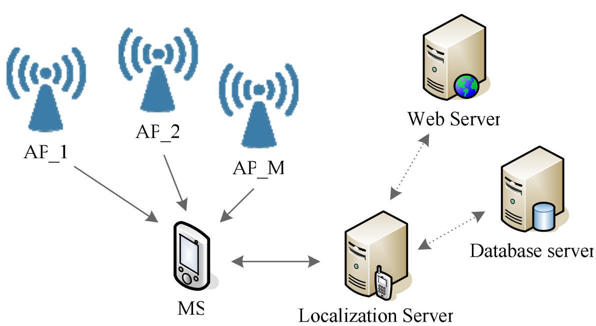


**Fig. 2.** Radio map for fingerprinting using RxLev.

The system is based on client-server architecture. From different point of view the entire architecture could be divided into three almost independent parts:

1. localization server,
2. network of access points,
3. mobile station - user, client.

The division was purposely performed, because of function of particular parts.

**Localization Server**

The core component of the system is the localization server. It is main brain of the system and provides more functions: communication with clients, position estimation, radio map database… Therefore, it consists of more functional entities: database server, web server and communication platform. LCS is built on Ubuntu operating system [18].

Radio map is saved on database server based on MySQL platform, which is free to use [19].

Communication between client-server is implemented via Simple Object Access Protocol (SOAP) web services. Web services are deployed at web server. They are used to upload measurement data to database server as well as exchange data when localization occurs. Web services technology offers reliable data transport and cross-platform object exchange.

Communication between client and LCS could be implemented by various standard communication links depending on availability. Obviously, Wifi is used by default, but Bluetooth, UMTS (Universal Mobile Telecommunications System) or GSM (Global System for Mobile Communications) were successfully tested.

**Network of Access Points**

Network of access points can consist of various network provider APs. It is one of the biggest advantages of the WifiLOC, because in this case it is not necessary to build new network for this purpose. Hence, initial costs are minimal.

The signals from all fixed AP are passively scanned and utilized for positioning. The system relies on fact that transmission power is not changed.

**Mobile Station**

Mobile station can be any mobile phone, personal device, tag or laptop equipped with IEEE 802.11 chipset. Localization application is developed in Java language SDK (Standard Development Kit) due to its easy implementation and cross-platform compatibility.

### 3.2 Positioning Data Visualization

Positioning data visualization is the same at the client application and LCS. Obviously, it depends on hardware equipment of the MS. Given positioning data is shown by means of web page, which is generated by web server, arbitrary web browser could be used to display them. Generally, the positioning result would be depicted in three levels:

1. Local - the web page displays local map (ground plan) and estimated position (spot) in local space. It is exact information about corridor or room where client is situated. This information is important for better orientation of the client in current area.
2. Sub-Global - in this level the actual building is identified where client is situated. This additional information could be used by client for better orientation in case of the next navigation in the building complex.
3. Global - the web page displays map and estimated position in global space. Maps are created using Google Maps™ API. This information is important for better global orientation of the client.

This information could be supplemented by exact coordinates of the place or picture which can be seen by user. It depends on implementation of the WifiLOC system, e.g. there could be information about the nearest physician surgery in hospital etc.

In Fig. 3 Client application can be seen on the mobile terminal. The application displays in text form that the user "Smolyk" is currently located in room number ND321. The user can decide to show different way for position data visualization via icons in application (see Fig. 3). There are shown various types of positioning data visualization in Fig. 4. The visualization could be seen at client and server.


**Fig. 3.** WifiLOC client application environment.

Design of "extensible" positioning system was the main idea during development phase. "Extensible" means that system should be able to implement in all relevant Wifi networks. The system is extensible from service extension point of view. The service portfolio could be extended without necessary modifications in mobile stations. The system does not have any limits from a number of users' point of view.

Next system advantage consists of the possibility to fill up data to database by a user in case that its terminal is able to use local coordinates, because WifiLOC is based on local coordinates system. This option can be used in case that a user needs further radio map (higher density of RSS information). These data can be easily converted to GPS coordinates as reference coordinates. Hence, advantage of the system consists of this fact, because results of mobile positioning can be also presented in WGS-84 (World Geodetic System) and are compatible with GPS and maps, which are


**Fig. 4.** Positioning data visualization.

based on WGS-84. The process of map creation is started and finished from the device which performs measurements to radio map. Positioning data (RSS and coordinates) is measured during this process. When all desired data is measured, they are sent to the server. In that case, reference points are marked manually in the map. The other way lies in association of reference points with fixed points, e.g. doors, offices and others. Finally, the most important advantage is that the WifiLOC system is independent on surrounding Wifi network operators. The system only utilizes information about signal strength from these networks. Arbitrary network can be used for communication between user and localization server.

## 4 Conclusion and Future Work

We designed the positioning solution based on fingerprinting method and network based on IEEE 802.11 standard. It is called WifiLOC. This system seems to be good appropriate solution for user adaptive systems which need to know user position in indoor environment. The solution uses received signal strength information for its function. The solution is implemented as mobile-assisted positioning. The mobile terminal independently collects the necessary data from surrounding access points. The measured data is sent from mobile terminal to the localization server for position estimation. The server estimates position and the information about position is sent back to the terminal when it is requested. Position information can be displayed on the map of terminal screen as well as at the server.

User position information is very important for user adaptive system. This task is performed by WifiLOC. According user's position can be offered various location based services and whole system can be adapted.

Future works can be focused on investigation of influence of various kinds of environments on positioning accuracy or how to increase of positioning accuracy. An accuracy improvement could be made with current localization algorithm, but more spots from database would be used for position estimation. It could be also based on different map matching algorithm or on the use of other extra data for position estimation.

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The book consists of 35 extended chapters which have been based on selected submissions to the poster session organized during the 3rd Asian Conference on Intelligent Information and Database Systems (20-22 April 2011 in Daegu, Korea). The book is organized into four parts, which are information retrieval and management, data mining and computational intelligence, service composition and user-centered approach, and intelligent management and e-business, respectively. All chapters in the book discuss theoretical and practical issues related to integration of artificial intelligence and database technologies in order to develop various intelligent information systems in many different domains. Such combination of artificial intelligence and database technologies has been regarded as one of the important interdisciplinary subfields of modern computer science, due to the sustainable development of networked information systems. Especially, service-oriented architecture and global multimedia systems used on a number of different purpose call for these developments. The book will be of interest to postgraduate students, professors and practitioners in the areas of artificial intelligence and database systems to modern information environments. The editors hope that readers of this volume can find many inspiring ideas and influential practical examples and use them in their future work.

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