EXTRACTING AND USING POSITION INFORMATION IN WLAN NETWORKS

Antti Seppänen
Teliasonera Finland
Vilhonvuorenkatu 8 A 29, 00500 Helsinki, Finland
Antti.Seppanen@teliasonera.com

Jouni Ikonen
Lappeenranta University of Technology
P.O. Box 20, 53851 Lappeenranta, Finland
Jouni.Ikonen@lut.fi

Jari Porras
Lappeenranta University of Technology
P.O. Box 20, 53851 Lappeenranta, Finland
Jari.Porras@lut.fi

ABSTRACT

Availability of the position information enables a lot of services. In this paper the usage of position information in WLAN networks is discussed. The paper presents a positioning system for WLAN environment. RADIUS and SNMP services are used to collect the position information for the cell based positioning. Extracting location information is quite easy, but problems arise from differences in hardware capabilities. Also more accurate results can be received by adding positioning client software in terminal devices. Results for positioning experiments are presented, comparisons to commercial systems are done and some recommendations are given.

KEYWORDS

Positioning methods, Cell based positioning, WLAN

1. INTRODUCTION

Wireless local area networks (WLAN) [1] have become very popular in just a few years. Bare wireless network has not brought much new, besides of the Ethernet extension, but it does not have to be that way. The whole new class of services can be introduced. Wireless local area network products have provided users some movement freedom in their offices. WLAN access points are used mainly to extend the wired network and besides of the freedom of movement there has not been much new. Access point usually allows users to move inside of 50 meters radius from the nearest access point with their laptop. Wireless network can give other benefits to the users besides of freedom of movement – they can also be used to provide wireless VoIP or position information. In this paper positioning is discussed and for sure there exists plenty of usages for position information.

There exists strong need for positioning. This is obvious with tourists and business travelers, who have to find their way around in new cities. As there exists need for positioning, why not provide position information as it can be done quite easily in WLAN.

Usage of position information can be divided in two basic categories, which are business use and entertainment use.

For business purposes positioning has a lot of applications. Some of these are e.g.:

- Tracking of vehicles. Estimation if busses are on schedule. Location of the nearest taxi. Location of city's service vehicles.
- Security. User is on allowed area. Security personal has checked required areas on schedule.
- Guidance. User is guided in an office building or in city streets.
- Advertisements. User gets different advertisements in different parts of a shopping mall.

Entertainment usages for positioning:

- Games. In traditional games like Nethack, there was a lot of action in dungeon during full moon. Location where the user is playing the game can add a whole new perspective to the game. There already exists cellular phone games, where users position is taken into account and users have to be close by to engage to battle. Example of such a game is Botfighters [2].
- Chat. User groups can easily be formed for users in same shopping center.
- Dating. Internet dating services are popular. A new twist can be added by informing user that near their current location is another user who has a potential dating profile.

In this paper the basic technologies how position information can be extracted from the wireless network are researched. Position can be extracted by studying the network devices. By adding a specialized positioning client to the terminal the device can be used to improve the accuracy of the positioning. The accuracy of the positioning is tested by experiments and the results are presented.

Some other work done with positioning in WLAN networks are presented in [3], [4], [5] and [6]. In Microsoft's research [3] signal level map has been used to implement an accurate positioning system. Signal levels and the corresponding position around the building are stored in a database and the levels are compared to the measurements that a wireless terminal sends to the server during positioning. Two methods are used building the database: empirical measurements and radio propagation models. The empirical method seems to be more accurate than the modeling providing the median error distance from 2 to 3 meters. The effect of the user orientation and multiple nearest signal measurement points are also considered in this paper.

In [4] the basic principle is quite the same as in [3]. In addition to the previous paper this research implements Extended Kalman Filter in the positioning system. Filtering is used to shape the continuous positioning data and this way erroneous results are filtered. During the test run the root mean square accuracy was observed to be about 3 meters. In [5] a calibration method is introduced and it is used together with Extended Kalman Filter. The calibration method is used to calculate an attenuation function for each access point that is used in positioning system. These functions produce corrections to distance estimates that are calculated based on signal attenuation. Because of the differences in radio field characteristics near each access point the attenuation correction is needed to get better results. The corrected values are delivered to the Extended Kalman Filter. The mean absolute error for this method is 1,5 meters.

In [6] positioning is researched based on signal propagation time. The time difference of arrival of radio signals from wireless terminal is measured in specific Geolocation Reference Points (GRP). These points must be synchronized very accurately. The exact time of arrival is measured from symbol synchronization pulses that precede each transmitted frame. The paper concludes that the best timing accuracy with minimal errors is approximately 20 ns. This represents the error of 6 meters. However, positioning tests were not conducted.

2. POSITIONING IN WLAN ENVIRONMENT

Depending on the requirements different kinds of positioning systems are needed. Positioning accuracy is a crucial factor when selecting positioning system for different services. Cell based positioning is one approach that can be used for positioning with coarse accuracy. In cell based positioning location of terminal is found only on accuracy of a size of wireless cell. In wireless LAN this corresponds to accuracy of 50-300 meters. In this paper the cell based positioning is implemented by taking advantage of either RADIUS [7] or SNMP capabilities of the access points. These methods are described in details in the following paragraph. To enhance the accuracy that the cell based positioning provides it is needed to examine the physical behaviour of the received radio signals. For example signal strength is affected by attenuation and multipath propagation and the transformed signal can be used in the client assisted positioning discussed later. It should be noted that all wireless LAN access points do not support RADIUS or even SNMP.

2.1 Cell based

Cell based positioning simply means defining the position of a terminal based on a wireless cell that serves the terminal. There are two options for cell the based positioning. One option is to use RADIUS based authentications and the other is to enquire access points about their clients via SNMP. The usage of RADIUS gives position information faster and with less network traffic, but is more rarely available in access points.

2.2 Cell based positioning using RADIUS

In the cell based positioning wireless terminals are positioned with an accuracy of an access point cell. If the access points support RADIUS authentication as an access control method this feature can be used to build a positioning system. In our setup Cistron RADIUS [8] server was used. RADIUS authentication server receives an enquiry every time a wireless terminal is associated with an access point. The terminal can be either activated within the service area of an access point or it can be a roaming device that has just moved to the service area of an access point. In both cases RADIUS services are used. Figure 1 presents a situation where a terminal associates with an access point and authentication is requested from the RADIUS server.

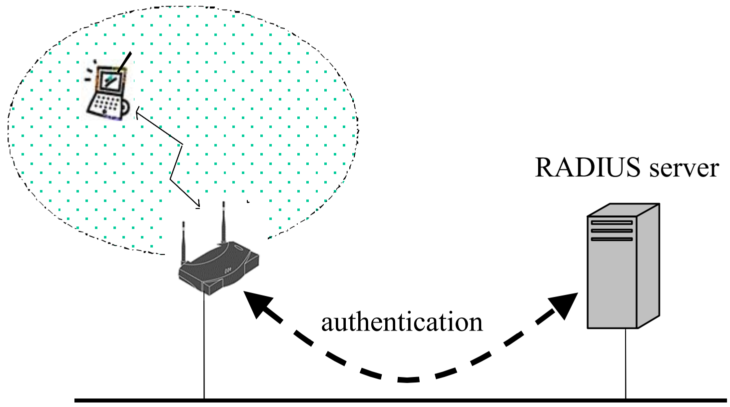
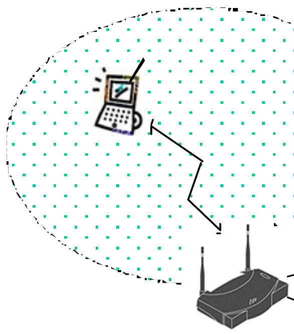


Figure 1. Structured wireless network with RADIUS server

Usually RADIUS server logs all the enquiries it receives. Using this information the positioning system always knows the last occurrences of wireless terminals and the access points that are serving them. To make the positioning system more efficient RADIUS log file was parsed on a continuous basis and the information was stored in SQL database. Of course, there is a possibility that the terminal that is to be located has been deactivated after the last RADIUS enquiry. In this case the last occurrence is not valid anymore. However, problems can be avoided if the activity of the terminal is first determined. The active terminals can be separated from the inactive ones for example by "pinging" them if the IP address is known. The usage of RADIUS is fast way to update the location of a terminal device and should be used if access points support it.

2.2.1 Cell based positioning using SNMP

Some statistical information can be collected with SNMP protocol from the access points. There is also a list of detected MAC addresses of the terminals in every access point. This list is called Bridge Learn Table. In addition to the terminals' MAC addresses this table also contains the index of the interface that has been used by the client. By requesting the corresponding entry of this table from every access point it is possible to find out in which access point the terminal has been connected to the wireless interface. Figure 2 presents a wireless terminal that associates with an access point and access point's Bridge Learn Table is updated.



MAC address	Interface
xx:xx:xx:xx:xx:xx:xx	ethernet
yy:yy:yy:yy:yy:yy:yy	wireless
...	...

Figure 2. The structure of a Bridge Learn Table

The problem with this approach is that the tables are not always up to date if the access point has lost its connection to the client. In that case the positioning result indicates more than one access point that has served the terminal through the wireless interface. To get their tables updated access points need to receive a frame from the terminal through another interface (for example Ethernet). This takes undefined time because the terminal may not have any reason to send frames to the old access point. However, update takes place for example during ARP broadcast sent by the terminal or as a result of a normal network traffic when the client communicates to another terminal served by the old access point.

Access points can also be forced to provide information about the terminals they are serving. The information collection process is started by sending SNMP requests to access points. After receiving the requests access points fill specific data fields with information about their terminals. The information contains the MAC addresses and the host names of the terminals. These information fields can be retrieved with SNMP protocol and they can be used to position the terminals in the cell based positioning system. This method is not very efficient though because each positioning process needs to enquire all the access points. Delay getting position from access points can be larger than what is suitable for many services.

Considering the performance of the cell based positioning system a couple of measurements were performed. Searching the position using SQL database took generally over 100 ms, while enquiring a MAC address from a bridge learn table took under 100 ms. However, using SNMP produces more network traffic and also loads access points, so the difference between the measurement is not an important factor. Another SNMP method, information collection process, took more time to produce results. Starting the information collection process and receiving the results took approximately 500 ms. These figures should be used only comparing the performance of the different positioning methods. Depending on the network structure (and many other aspects) the absolute values will differ from what is presented here.

2.2.2 Client assisted positioning

Better positioning accuracy can be achieved by probing signal strengths from several access points and then associating those strengths with the corresponding position. In the first phase the test measurements are performed by the system administrator in order to create fingerprint of the mapped area and the results are stored in a database. In the second phase the wireless terminal is positioned by comparing the measurements from the terminal and from the database together. The value set that produces the minimal separation is selected to represent the position of the network device. Fingerprint of an area can be also created by simulation, but results should be always verified by measurements.

In Figure 3 the terminal receives signals from the access points A and B. The terminal measures the received signal strengths from both of the access points and sends the results (M_A, M_B) to the server.

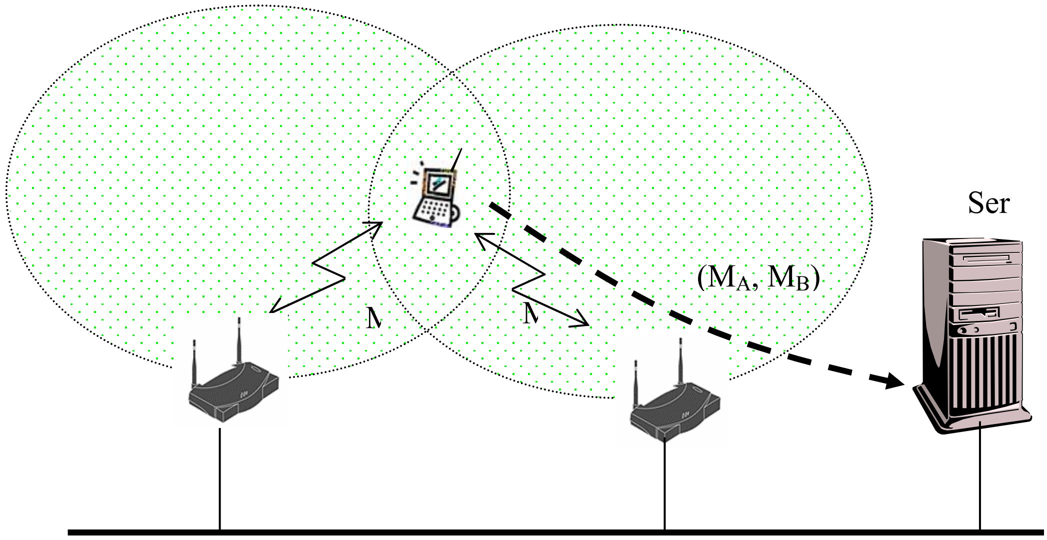


Figure 3. Measurement results are sent to the server

Table 1 presents the structure of the database including position coordinates and signal strengths. In the test phase the signal strengths are compared to the values that are received from the client and difference is calculated. The row that produces the smallest sum of the differences also indicates the positioning result in the form of the coordinates.

Table 1: The structure of the positioning database

Position coordinates		Signal strengths from access points		
X	Y	Access point T1	...	Access point Tn
x_1	y_1	$T1_1$	…	Tn_1
…	…	…	…	…
x_m	y_m	$T1_m$	…	Tn_m

An example of equation that is used to calculate the sum of differences is

$$|T1_i - T1_c| + ... + |Tn_i - Tn_c| \tag{1}$$

where subscript *i* is the line number of the database and *c* indicates the values received from the client. As a result the smallest sum indicates coordinates x_i and y_i.

A wireless terminal that is used to collect signal strengths must be able to change its channel in order to receive signals from all the access points that are detectable. Each channel is listened for the beacon frames that are repeatedly sent by all the access points. A default beacon period is 100 ms, so that is also the default waiting time for each channel. If a beacon frame is received it has to be studied in details in order to find out the network name (SSID) and the transmit channel number that are included in each beacon frame. It is important to know the network name inside a beacon frame to avoid confusion with frames from other overlapping networks. The transmit channel number needs to be extracted from a beacon frame because of a crosstalk. Transmission on a channel spreads over a group of five channels. To make the signal strength measurements as accurate as possible only the beacon frames that are received from the same channel that they were sent to are taken into account. Only when these two properties of beacon frames are true they are eligible for the positioning software. At this point channel waiting time is extended to approximately ten times the default value and that enables the positioning software to receive ten beacon frames from a channel. After each reception the corresponding signal strength is requested from the physical layer and before changing a channel the average of these signal strengths is calculated. The average value is the final signal strength for the access point concerned. The signal strength between frames can fluctuate heavily and the average value is needed to compensate those fluctuations.

When using client assisted method access point cells should be partly overlapping because client should be able to receive signal strengths from several access points at a time. The number of detected access points can affect the positioning accuracy. The accuracy is also dependent on the amount of database entries that are stored in the first phase of this method. With coarse measurement points the positioning estimate is not as accurate as it is with dense ones. Selecting two closest value sets from the database and calculating position estimate to be located between them can enhance the accuracy especially with coarse first phase measurements.

Both cell based and client assisted positioning can be used. However due to the support problems for non-standard positioning client software in various operating systems and OS versions, the much easier way to apply positioning is to use only standard software in terminal devices. Collection of location information is not very difficult, but it leads also to privacy questions. Operators can collect location information, but are they allowed. If collection of location information is allowed who can get the information? Will the user explicitly allow each service to use his information? These are some of the issues that need to be solved before positioning services can be generally offered to the customers.

3. RESULTS

Tests were first performed with the cell based positioning system. An office building floor with three access points was selected as the test area. Figure 4 presents the maps of the floor and the three access points with their coverage areas. The length of the floor is approximately 70 meters and the width is 50 meters. Grey areas indicate positioning results from access points A, B and C using the cell based positioning system. The test shows that cell based positioning is accurate enough for many services like gathering group of users in the same chatting service or advertisement services in a shopping mall. The positioning system is easy to implement and interaction with the user or the client is not needed.

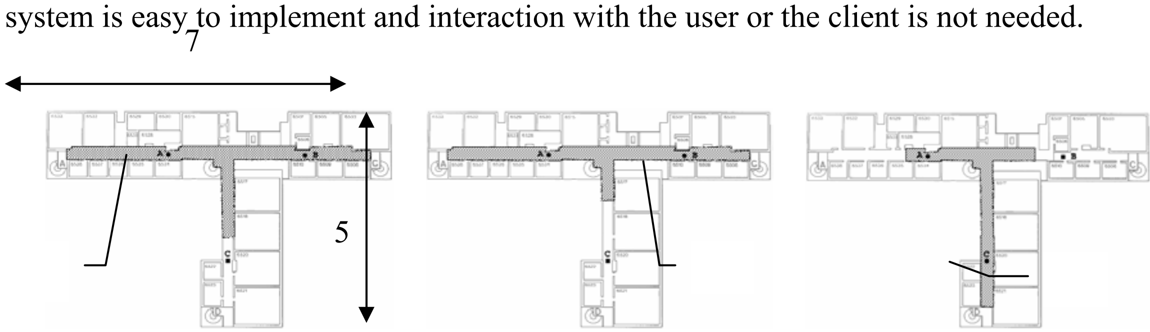


Figure 4. Accuracy of the cell based positioning system

The same floor was mapped to be used with the client assisted positioning system. In the setup phase (first phase) measurements had 4 meters distance and in the test phase (second phase) the distance between measurement points was 1 meter. According to the test measurements the median of error distance for client assisted method is ±3 meters. Figure 5 presents the cumulative error probability as a result from the tests.

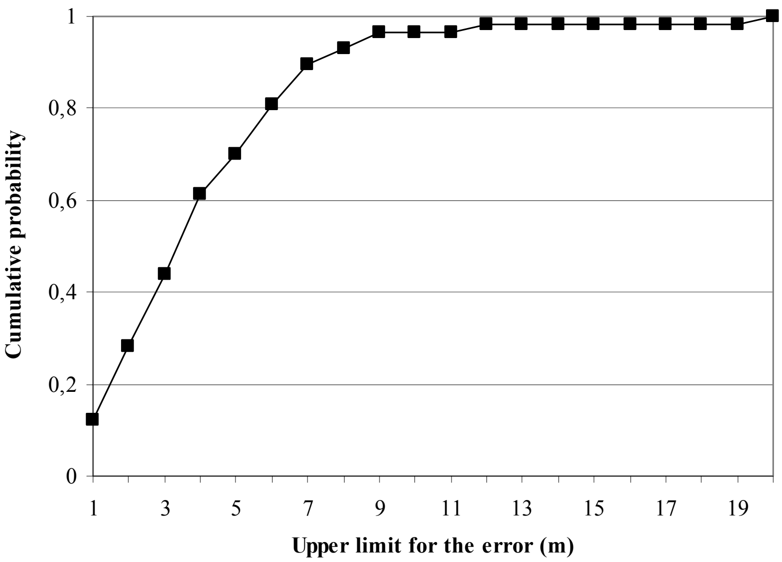


Figure 5. Accuracy of the client assisted positioning system

The test shows that there is an occasional possibility to get quite big errors with this method although most of the errors are below nine meters. The biggest error in the test was 20 meters. This has to be taken into account when using this positioning method with other services. Generally, the client assisted positioning system is more complicated to implement than the cell based positioning system. Compatibility with WLAN cards from different vendors might be a problem. Another source of error is changing radio characteristics. The amount of people, for example, can affect received signal levels and this behaviour can cause impaired positioning accuracy. Also more permanent changes like new furniture can affect radio signals and in this case the database may need updating if the changes are severe.

4. NOTES ON COMMERCIAL WLAN POSITIONING

In course of research commercial position systems have emerged. There are product e.g. from Bluesoft [10], Ekahau [11] and Pango Networks [12]. Some of these position systems promise quite good accuracy. We tested Ekahau's position engine by writing a small game for it. Their system requires the use of client software in the devices to be positioned, i.e. the system is using client assisted positioning.

Use of positioning software is started by selecting area, where we want to apply positioning. It is recommended that at least three access points should be heard everywhere on that area. The task is continued by creating a fingerprint from the selected area with a laptop (or laptops). This is done by walking around and clicking map to make measurements. Figure 6 shows a map of a research laboratory. After enough measurements are made the data can be used for positioning.

Position engine can be interfaced also through Ekahau positioning API. In tests this API was used to write a simple tag game, where users walk around and try to avoid tag. Creation of the tag game is very straightforward process and most users can create simple applications in less time than one day. It can easily be seen that positioning will create a bunch of new interesting applications to be used together with WLANs.

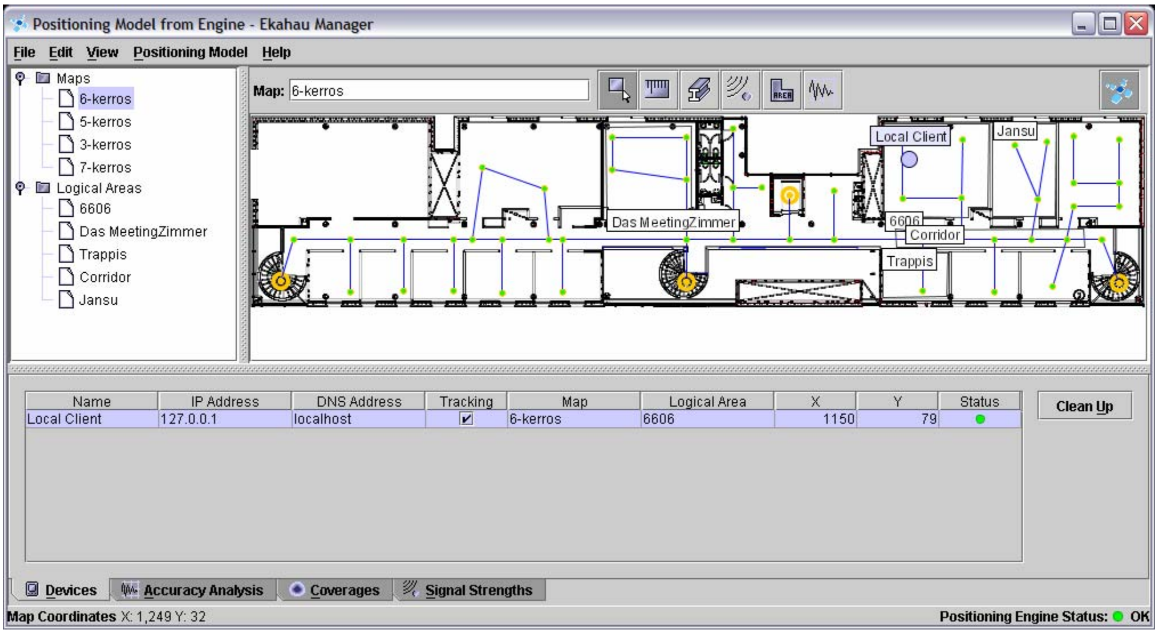


Figure 6. A view from Ekahau's positioning engine

Comparison of Ekahau's commercial position system to our laboratory system, we have to say that our simple client assisted position scheme is not enough accurate e.g. for the tag game. However cell based positioning is often sufficient and does not require special client software to be used. We see the requirement of propriety client software as major obstacle for many public services.

5. CONCLUSIONS

According to the experiments RADIUS service and SNMP protocol can be used to perform cell based positioning. Searching through RADIUS log file is an efficient and scalable way to position a wireless terminal. Using SNMP protocol is not that scalable since the amount of SNMP queries increases with the number of access points. More accurate client assisted method needs specific software in every client and because of this limitation it cannot be used by new clients without installing the software. This system also needs a client to start the positioning process or at least the client software must be running and approval from the user must be received before the server can initiate positioning. Only cell based positioning methods are suitable for positioning services that do not need any action from the user.

It is recommended that cell based positioning is used if the accuracy is sufficient for the application. This way no additional software is needed in the client devices. In the introduction some examples of applications were presented. Among these examples there are applications that require positioning accuracy of couple of meters and that indicates the need for client assisted positioning. These applications could be: Guidance in a building and Advertisements. For the rest of the examples (Tracking of vehicles, Security, Games, Chat, Dating) the requirement for accuracy is not that tight. Of course there are some cases when this division is not applicable and the accuracy requirement has to be defined for every application individually.

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