INFLUENCE OF THE MOBILE DEVICE HEIGHT ON THE RSSI IN A WLAN POSITIONING SYSTEM

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Abstract: *A WLAN Positioning System does not provide distances, but Received Signal Strength Indicators (RSSIs). In order to calculate distances out of the RSSI, information about the actual position in the environment of the Reference Points (RPs) and Test Points (TPs) must be integrated in the post processing phase. For the database of fingerprints (the radio map containing RPs and their correspondent RSSI) to be built, a certain number of calibration measurements must be performed at each RP with respect to the orientation between the transmitters and the receiver. Moreover, parameters of identification as height, heading, human body presence, integration time, distance, must be taken into account when performing the fingerprinting measurements. Due to factors such as multipath, attenuation or shadowing, the RSSI is better behaved at certain heights of the receiver antenna, respectively the Mobile Device.*

Keywords: *Indoor Navigation, WLAN Positioning System, fingerprints, height*

1. Introduction

Universities, offices and many private homes utilize IEEE 802.11 set of standards to get rid of wires. As a reaction to the proliferation of IEEE 802.11, almost all modern Mobile Devices (MDs), ranging from smart phones to laptops, are equipped with built-in 802.11 network interfaces [2]. The huge population of MDs provides a powerful platform for positioning which can enhance the Indoor positioning performance in certain environments where the satellite signals are obstructed. The growing interest shown to WLAN Positioning Systems appeared mostly due to the fact that Access Points (APs) can be found everywhere in the daily environment in order to provide fast and best coverage mobile access to the Internet. The rapid growth of location-aware services represents also a good motivation to develop techniques for high precision estimate of the mobile or static devices location. Due to their ease of installation and their good rate mobility for data, WLAN networks have become very popular means for offering wireless networking facilities for all users [1], and opening a big market to develop WLAN Positioning Systems (WPSs) able to ensure localization in both Indoor and Outdoor environments with high accuracy and availability. Many of the Indoor navigation tasks are characterized by high precision requirements of a few centimetres. Thus, the question is whether the existing navigation systems can answer these demands.

2. IEEE 802.11b Wireless LAN (WLAN) set of standards

IEEE 802.11 is a set of standards created and maintained by the IEEE 802 LAN/MAN Standards Committee for ensuring wireless local area network (WLAN) communication in the 2.4, 3.6 and 5 GHz frequency bands. The most utilized protocols are 802.11b and 802.11g [7].

IEEE 802.11 divides the radio frequency spectrum into several channels. The type of available channels depends on which sub-specification of the 802.11 physical layer is selected [2] and on the country or location where the 802.11 protocol is being used. For example, in Europe, for the standards 802.11b and 802.11s there are allowed 13 channels, while in USA can be used only 11 channels. In order to detect the signal provided by the APs situated in close proximity, the MD must adjust its WLAN network interface to each channel (one after another), and then perform a scan, due to the fact that the wireless network interface controller (WNIC) follows only one channel at a certain time.

By evaluating the RSSIs transmitted by several APs, the user's position can be calculated. In order to have its location determined, a MD performs active or passive scanning to obtain knowledge of visible APs and measurements of the Received Signal Strength Indicator (RSSI) from the nearby APs. The active and passive scanning are techniques performed for learning about the signal reception quality of APs and their presence within the communication area.

This paper mainly focuses on 802.11b standard due to the fact that it is the most readily available. Furthermore, the scenario is located in Europe, where, as said before, 802.11 standard works on 13 channels.

3. Wireless LAN and the Received Signal Strength Indicator (RSSI)

Indoor positioning challenges and outcome have failed to attract attention until recent years [6]. The main reason which led to this disadvantage is the fact that the infrastructure for Wireless Local Area Networks (WLAN, also known as Wi-Fi) was incomplete, and the second reason was the limited market demand. For several years, with the increasing use of mobile computing devices and social networking communities/services, such as smart phones, Personal Digital Assistants (PDA), laptops, notebooks etc. equipped with a built-in WLAN card, WLAN USB stick/adapter or other mobile appliances, web 2.0 (Facebook, Twitter, e-communities etc.), and the fact that WLAN is nowadays commonly available in more and more buildings, public spaces, urban areas and beyond, Indoor WLAN Positioning Systems (WPS) based on WLAN infrastructure have experienced a rapid development.

The APs represents the base stations in the WPS and they transmit and receive radio signals for wireless compatible devices to communicate with. The MD is the user in the WPS and it is equipped with a wireless network interface controller (WNIC) which has the role of collecting data transmitted by the APs, namely RSSIs. In general, WNICs are compatible with IEEE 802.11 set of standards, they have wireless transfer rates (Mbit/s) ranging from 2Mbit/s to 54 Mbit/s and their transmit power is measured in dBm [4].

A Location-Based Service (LBS) is an application that acts according to the position of the MD, or is offering proactively/instant location-dependent information to the user. A LBS or wireless location service represents a positioning technology accessible with MDs through the wireless network. LBS are able to make use of the geographical position of the MD in order to identify a location of a person or object, i.e. to return a location-specific service result, namely the location estimate.

The Industrial Scientific and Medical radio bands (ISM) represents portions of the radio spectrum, originally reserved for the use of Radio Frequency (RF) energy for industrial, scientific and medical purposes, different than communications (e.g. RF processing heating, microwave ovens, medical diathermy machines). ISM is an unlicensed band in which the Bluetooth technology operates. The powerful emissions are able to create electromagnetic interference and disrupt radio communications using the same frequency, so these devices were limited to a certain band of frequencies. In recent years, these bands have also been shared with licence–free error–tolerant communication applications such as WLAN Sensor Networks (915 MHz and 2.4 GHz frequency bands), as well as Wireless LANs (WLAN) and cordless phones (915 MHz, 2.4 GHz, 5 GHz frequency bands).

The RSSI is an integer value, in arbitrary units, ranging between 0-255 with maximum values differing from manufacturer to manufacturer, which shows an indication of the power level of the signal transmitted by the APs in the network. The RSSI is defined in the 802.11 set of standards and is intended to be used by the microcode on the adapter in a wireless networking interface controller (WNIC) also mentioned as Mobile Device in this paper [8].

There is no standard relationship defined between the RSSI value and the power level in [mW] or [dBm], each WNIC manufacturer delivering their own precision, granularity and thresholds for the actual power measured in [mW] or [dBm], and their own range of RSSI values. Thus, the RSSI can be positive or negative.

Following only one channel at a time, the MD must be able to determine whether the channel is clear and no other device is transmitting, in order to transmit a packet of data. If the amount of signal strength transmitted by the APs is below a certain threshold previously established for each MD, then the chipset within the device is informed that the channel is clear and the network card is clear to send (CTS) data. Afterwards, the MD is able to receive a RSSI value and its corresponding timestamp (the timestamp is provided only if the manufacturer chooses to implement this option in the software), making use of a wireless network monitoring software such as inSSIDer, NetSurveyor, Wireshark, Kismet or Xirrus.

4. Case Study

The location of the tests performed with the WPS has been established in building 42 of the Institute for Space Applications and Space Technologies, Faculty of Aerospace Engineering – University of the Federal Armed Forces Munich, Germany. The architecture of the building is complex, with different room and corridor types, and obstacles such as doors, furniture etc.

The experimental test bed has been divided into a network of 69 Reference Points (RPs), carefully selected with respect to the obstacles in the environment, and a number of 6 Access Points (APs) have been symmetrically deployed in the test bed. A database of Received Signal Strength Indicator (RSSI) patterns, also called a radio map, which provides information about the radio signal properties as a function of position is going to be built on the local frame of RPs. Each value in the database represents a mapping between a position and a location fingerprint. As seen in Fig. 1, the RSSI measurements at different heights have been performed in Test Point (TP) no. 4.

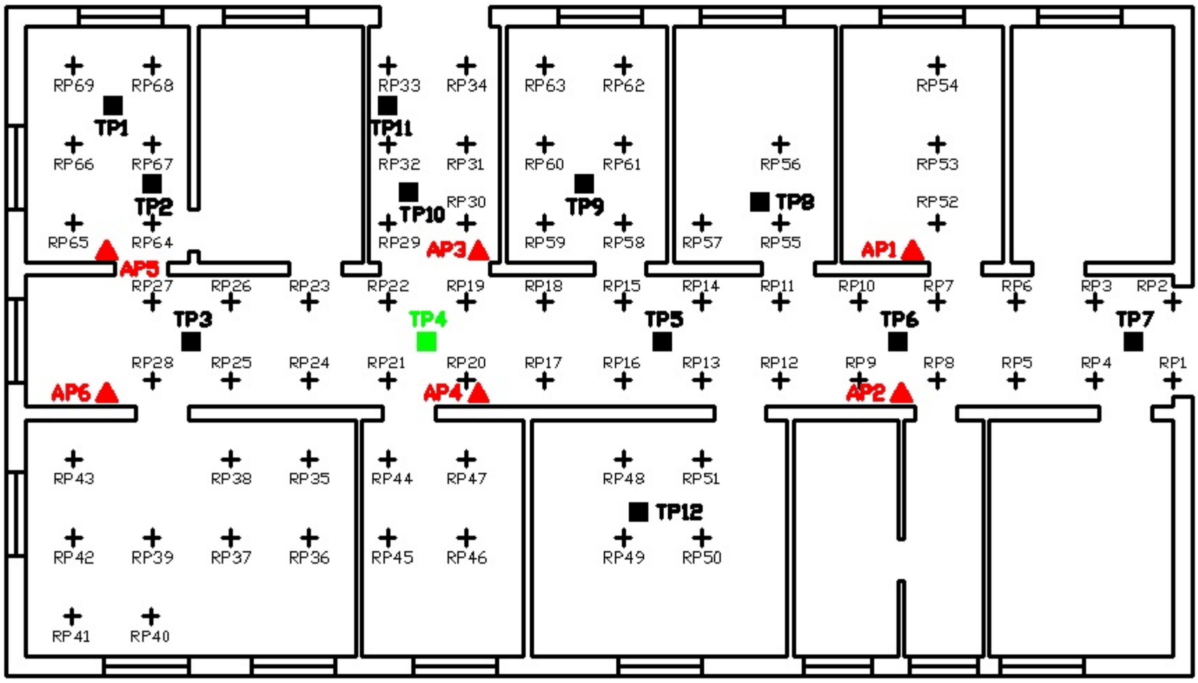

Fig. 1 – Building layout – complex architecture

The MD used for performing WLAN measurements is an MSI PR210 notebook with the following specifications:

- AMD Turion®64 X2 Mobile Technology TL-50 1.60 GHz Processor;
- 2 GB RAM;
- 1xHDD 150 GB;

The notebook has been equipped with a wireless network interface controller (WNIC) TP Link TL-WN821N USB Wireless Adapter compatible with IEEE 802.11n, IEEE 802.11g, and IEEE 802.11b standards.

The devices specifications are those reported by their developers.

The software used for collecting RSSI samples is inSSIDer, and for the post-processing phase, MATLAB R2011b.

The location fingerprinting method has been used for Indoor positioning purposes. A statistically based positioning technique such as the fingerprinting method can be divided into phases, therefore in the WPS case there are two phases, the offline phase and the online phase.

In the offline phase, multiple APs are installed over the experimental test bed in order to transmit WLAN signals which are collected using a MD. When a user equipped with a suitable device is present, the antenna of the MD will detect the RSSIs coming from the APs and specialized software will store the data in a log file. The signal strength is measured in order to create the radio map of RSSI patterns on the predetermined RPs, by performing a site-survey of these RSSIs over the entire area. The next step is to locate the MD at each RP, so that the RSSI of all the WLAN APs are being measured and the characteristic feature of that RP is determined and stored in the database together with its corresponding position information from the previous established local frame. The whole process is repeated until all RPs are visited.

During the online phase, the software receives measurements transmitted by the MDs. The RPs are being used to calculate the probable position of the MD, whose actual location is unknown. These new RSSI samples are compared with the values obtained from the offline phase, which yields a calculated position for each device, and once the received measurement is found to be correct, it will be used as input for the positioning algorithm [5].

The propagation of the radio signal in Indoor environments is under the influence of penetration losses through walls and floors, and the effect of multipath propagation. Furthermore, the signal is also affected by objects standing in the way between the WNIC and the AP (such as walls, furniture, open/closed doors, refrigerators, fuse boxes, metal plumbing etc.). Other sources of interference could be MDs such as smart mobile phones, laptops, cordless phones, microwave ovens, Bluetooth devices (which uses the same frequency band as the one used by the IEEE 802.11b standard, namely the 2.4 GHz band), large electrical appliances etc. The RSSI can be also influenced by the location and the movement of people inside the building, reflections on the walls and positive/negative interference of other signals.

The distribution of the RSSI is non-Gaussian and varies at the same location or at different locations when the orientation of the antenna changes [3]. Therefore, more measurements must be conducted in order to generate the database, and this increases the duration of the training phase in location fingerprinting. The database size and the computational load are also increased. Thus, parameters as orientation of the MD antenna, integration time, distance, human body presence were taken into account in order to overcome these problems.

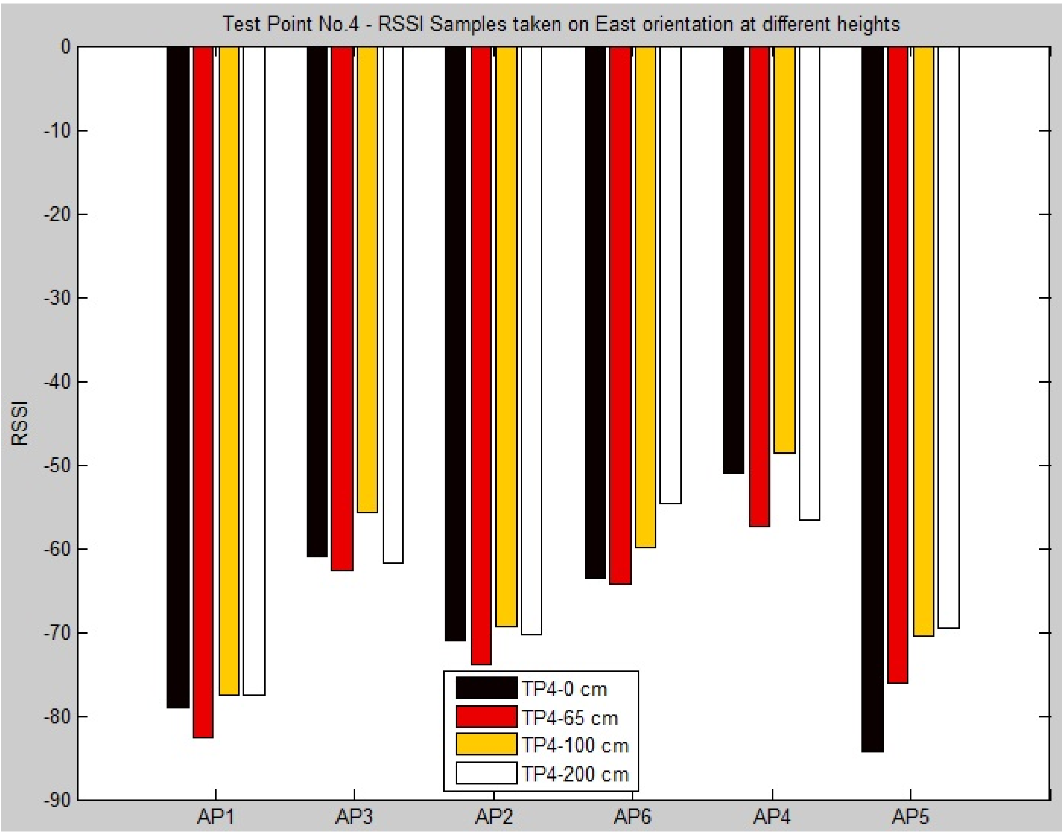

Fig. 2 – RSSI samples taken on East orientation at 0, 65, 100 and 200 cm height

As seen in Fig 2, the radio signal is attenuated due to the increase of distance between the AP and the MD, the interference from other signals and the orientation of the receiver's antenna. When a door opens, people are present or the orientation of the user changes, an offset of 5÷10 dB has been reported.

Measurements of the RSSI have been performed in Test Point no.4 considering only East orientation of the receiver's antenna. In order to observe the behaviour of RSSIs on different heights in the same TP, measurements were taken at 0.00 m, 0.65 m, 1.00 m and 2.00 m. The duration of collecting data samples was 5 minutes for each height, on the same measurement campaign. According to the results presented in Fig. 3, the worst scenario of collecting RSSI data is at 0.65 m. Furthermore, bearing in mind that for the chosen test bed, TP4 is placed on the main hallway, AP1, respectively AP5 are placed in two offices, with closed doors scenario, the RSSIs transmitted by these two APs are highly attenuated due to reflections on the walls. The offset of -15 dBm in the RSSI transmitted by AP5 on 0.00 m height case, in relation to the average value of RSSI in TP4 is caused by the placement of the AP on the floor, behind a concrete wall of 30 cm thickness.

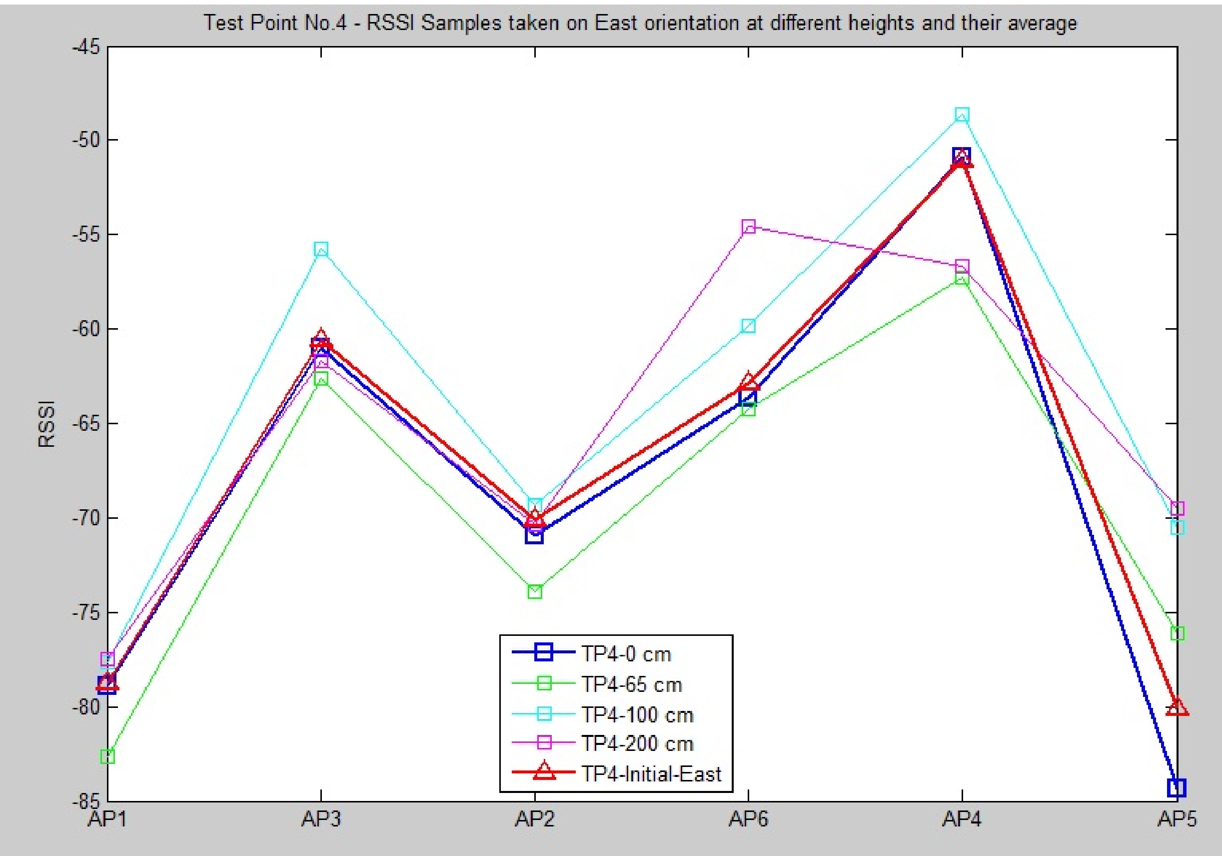

Fig. 3 – Influence of the MD height on the RSSI

A comparison between RSSI samples taken in TP4 with the MD on the ground floor, the initial measurement on East orientation on the ground floor and the average RSSI value from all height measurements shows that the same -15 dBm offset occurs (Fig. 4) due to phenomena like multipath, reflections and refractions which can provide different amplitudes and phases on the end receiver.

The RSSI is better behaved when the MD is held at the height of 1.00m.

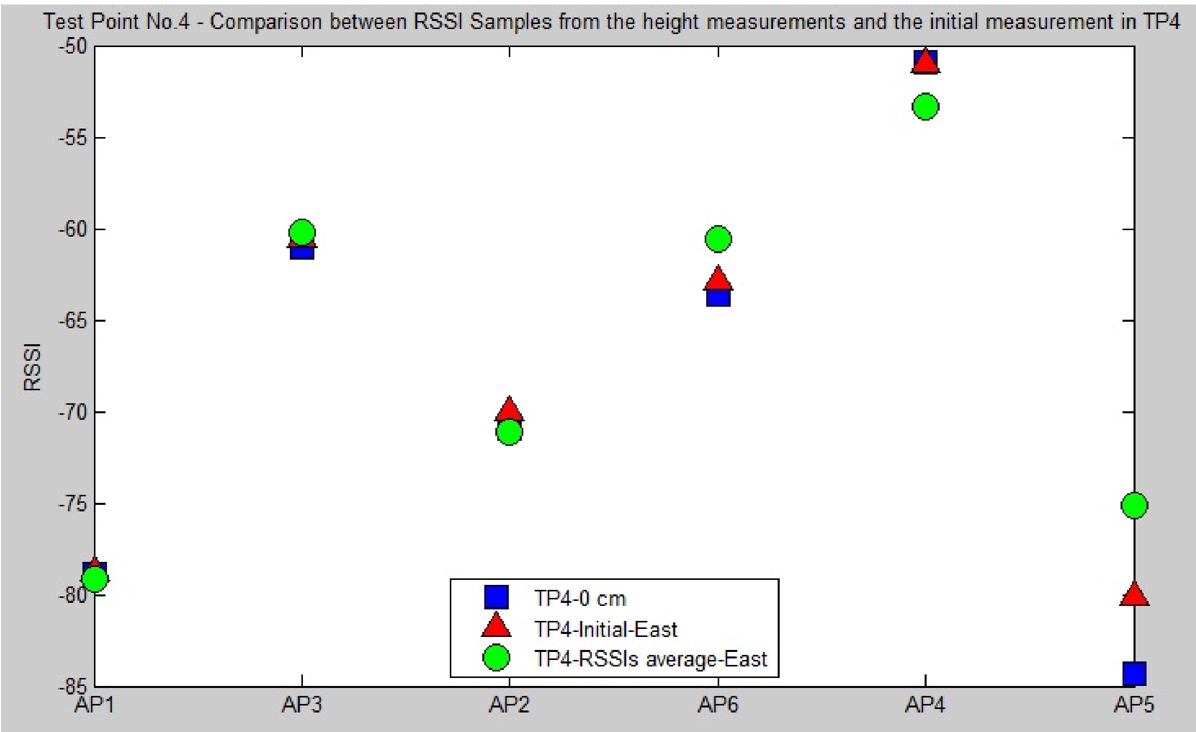

Fig. 4 - Comparison between RSSI samples taken on East orientation in TP4

5. Conclusions

When getting the WLAN Positioning System to work for the first time, it is mandatory to build a radio map of fingerprints during the offline (training or calibration) phase. The radio map must be so precise that the RPs coordinates in the local frame can be determined. To ensure an accurate location estimate of the Mobile Device, the spacing between two adjacent RPs, namely the granularity, must be small. When the RPs are gridded, close to a uniform distribution, and the granularity decreases, i.e. the number of RPs increases, the location estimate will be more accurate.

A high density deployment of RPs is unrealistic in most part of the localization scenarios and does not provide better accuracy, hence the number of RPs must be minimized. Therefore, the best configuration of a RSSI radio map has been established for this particular building, with respect to the environment and number of rooms. In addition, adding a new AP to the system does not improves significantly the accuracy in some areas, but improves it globally.

The fingerprinting method is affected by No Line of Sight (NLOS) conditions, due to the fact that the location estimate is influenced by the localization scenario and the radio propagation in Indoor environments also suffers from multipath fading effect. The obtained results following the experiments conducted have shown that a Mobile Device held at 1.00 m (for example a mobile phone in the user's pocket) is better localized, as well as MDs placed on the ground floor. Furthermore, a complete database of fingerprints built taking into account a series of training parameters such as the orientation of the receiver's antenna and integration time will cover all possible cases of variations in the user's position in relation to the Access Points antennas, yielding better positioning capabilities.

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