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# NAVIGATION SYSTEM BASED ON BLUETOOTH BEACONS: IMPLEMENTATION AND EXPERIMENTAL ESTIMATION

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## ABSTRACT

This work describes development of positioning model as well as implementation of algorithm of positioning based on Bluetooth technology without satellite navigation systems.

The research is aimed at development and testing of an internal positioning system using Bluetooth beacon with minimal error.

It is assumed that applying the methods of filtering and data smoothing to RSSI Bluetooth beacon data can significantly improve the positioning accuracy.

Some existing positioning technologies based on Bluetooth beacons are overviewed, development of Bluetooth propagation model is described based on RSSI data. Bluetooth beacons play two different roles: transmittance (beacon) and reception (device). This enables data exchange over short distances. Therefore, many researchers study intensively positioning methods using beacons. However, positioning is not always accurate. Positioning system based on Bluetooth beacons is proposed in this article. Improvement of positioning accuracy can be improved by smoothing and filtration of data from beacons.

**Keywords:** *Positioning, Indoor Positioning System, Bluetooth, RSSI, Bluetooth Beacon, Location Based Services, Navigation Data Smoothing and Filtration*.

## 1. INTRODUCTION

Despite numerous studies, positioning of mobile objects remains an urgent issue due to difficulties occurring upon performing this task. The most typical method of data acquisition is GPS (Global Positioning System). The accuracy of modern satellite navigation systems is satisfactory in many cases. This system presents positioning data by means of such devices as smartphones and portable navigators which determine distance or route to target location, thus decreasing expenses and time consumption. Despite the fact that GPS is a powerful and useful technology, its functions cannot be performed properly indoors, underground or in tunnels. As a consequence, it is required to provide adequate internal service of positioning, nowadays numerous studies are devoted to this task.

The research is aimed at development of an internal positioning system using Bluetooth beacon, as well as at experimental error verification.

Many researchers are actively exploring positioning methods using beacons. However, positioning is not always accurate. This article presents the development and experimental evaluation of a positioning system using Bluetooth beacons.

Hypothesis. In order to improve the accuracy of positioning, it is proposed to smooth and filter data coming from beacons, and it is assumed that applying methods of filtering and smoothing data to RSSI Bluetooth beacon data can significantly improve the positioning accuracy.

**Location based services and positioning.**

The major and widely applied technological platform for implementation of applications in transportation Ad-hoc networks is Location-based services (LBS) based on knowledge of position, they are supported by wide range of communications starting from short-range Bluetooth to global satellite technologies (Fig. 1).

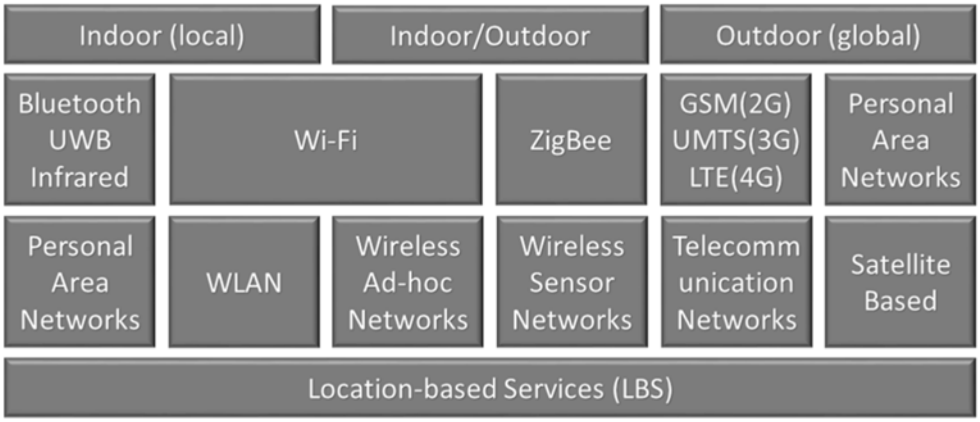

*Figure 1. Location-based services (LBS)*

The fundamental problem of positioning can be briefly formulated as estimation of point position in 2D or 3D environment in coordinates formed by other reference geometrical data.

Modern positioning systems are based on such basic data as distances and angels which can be determined indirectly by measurements of interrelated variables, such as signal strength, signal transmission time, transmission tie difference, phase difference, and others. New technologies made it possible not only to obtain more accurate measurements but also to develop new architectural solution of localizing systems, such as cooperative systems and data fusion systems.

Methods of object positioning in wireless networks are generally used for positioning of sensors with initially unknown coordinates with respect to certain sensors with a priori known coordinates available for required intersensor measurements. The sensors with a priori known coordinates are referred to as beacons. Beacon coordinates can be acquired by global positioning systems or as a consequence of beacon installation into geodesic determined point.

## 2. STATE-OF-THE-ART

Taking into account the importance of indoor positioning, some researchers pay great attention to wireless technologies, such as Bluetooth, Wi-Fi, GPS and other approaches to solution of this problem depending on transmitters. The issue of positioning was analyzed by several researchers. For instance, the estimation in [1] is based on Bluetooth trilateration, though, due to exclusive use of Bluetooth technology, this method is still characterized by high inaccuracy.

Altini et al. [2] proposed the method where Bluetooth transmitters are positioned according to previously known distribution and trained neural network required for positioning. In [3] it is proposed to apply received signal strength indicator (RSSI) data between several fixed wireless beacons in order to improve reliability of Bluetooth positioning by these data for calibration of sensor responses.

Bluetooth beacon flowchart is based on solution for indoor positioning as described in [4] and [5]. These methods are rather promising, because they can provide high accuracy, though, they require for previously generated radio map, hence, this method is time consuming and impractical, especially in large scale projects.

The approach in [6] applies wide availability of indoor signals of Bluetooth, Wi-Fi, and GPS sensors. This method is based on previous level of Bluetooth RSSI radio map as well as Wi-Fi radio. It is also assumed that there exists preliminary distribution of Bluetooth and Wi-Fi stations.

S. Zirari, P. Canalda, F. Spies [7] propose very simple approach which declares that it is possible to achieve good positioning estimations using GPS as major data source. It is proposed to apply solution of a set of at least four equations and one unknown. The four equations depend on the number of signals detected by receiver, and if the signals observed by GPS are insufficient for the set of equations, then it is supplemented by signals from other source, Wi-Fi in this case. Similar approach is used in this work where the set of equations will be supplemented by signals available in environment.

Huang used simple USB Bluetooth on PC in building as locators [8]. In this embodiment, mobile devices scan USB Bluetooth beacons in order to obtain information about distance. It was discovered experimentally that only RSSI did not provide accurate data for distance measurement. It was detected that communication quality was more suitable for determination of distance. Moreover, it was discovered that positioning was more suitable for moderate rooms with minimum obstacles providing detailed information for room scales.

Feldman et al. [9] developed very accurate mapping of test room onto spatial grid [9]. Using complete set of RSSI data for all room, simple mathematical mapping of RSSI distance was developed. Three Bluetooth access points were used, the accuracy of about two meters was possible when the access points and mobile devices were separated not more than by eight meters. It has been demonstrated that RSSI can be probably used for determination of distance if the room is known and empirical data are used for detailed mapping.

Halberg et al. detected that direct use of RSSI for distance prediction was problematic, extended studies of room and environment were highly requested [10]. The results demonstrated that certain rigid codes for room geometry and positions of Bluetooth access points were useful for achievement of accuracy up to 10 m.

The experimental results demonstrate that several antennas with high gain at Bluetooth access point with adjustable attenuators can provide more accurate results in comparison with simple RSSI measurements [11]. These systems perform several various and excessive measurements to provide more accurate results. Bandara et al. used this modern equipment in test room (intelligent room) where antennas were positioned statically and the access point recorded data from devices with Bluetooth support. Access point is connected to device and records RSSI data for each antenna while varying attenuation levels at antenna. Several backup readings of multiple levels of transmission power are used to improve accuracy. Improved Bluetooth access point in this version is good to solve nonlinear correlation between RSSI and distance.

Han Tao, Lu Xiaochun, and Lan Qi presented motion pattern recognition using the Kalman filter (PRKF) and applied it to the algorithm of time difference of arrival (TDOA) of internal localization [12]. The state matrix in the Kalman filter (KF) is determined by motion pattern according to which the target node should act, this could lead to a new system error if this assumption is wrong. Hence, initially three fuzzy sets were created using three KFs, the state matrices of which corresponded to various motion patterns; the simulation results demonstrate that PRKF can improve the localization accuracy more than by 20%.

Jiahong Li, Xianghu Yue, Jie Chen, Fang Deng proposed the confidence-based intersection method [13] which expanded the range of circle within a certain confidence interval. In this method, the confidence interval is estimated on the basis of the Cramér–Rao lower bound of the time of flight (TOF) measurement. Furthermore, an intersection determination method is proposed to select the intersection point with higher confidence level. The simulation and experimental results show the superiority of the proposed method in localization accuracy and robustness to noise compared to the conventional trilateration method, e.g., the centroid-based and least squares-based trilateration methods.

The lower transmission power of BTLE/BLE also contributes to the better performance of localization because it can reduce the multipath effect in some scenarios. Since the sensitivity of receivers is almost the same for both BTLE and Wi-Fi devices, in extreme cases the receiver can only hear the most powerful signal component, e.g., the line-of-sight signal, while all others are filtered out [14]. Also, Ramsey Faragher et al. demonstrated that significant positioning improvement over Wi-Fi was possible using even a relatively sparse deployment of beacons once the characteristics of BLE signals were accounted for [15]. Suining He et al. implemented Tilejunction, simulation and experimental measurements, showing that it outperformed other recent state-of-the-art approaches (e.g., RADAR, KL-divergence, etc.) with significantly lower localization error (often by more than 30%) [16]. Meanwhile, BLE technology provides the variables that can be used to predict the position information. One of those variables is the RSSI, which may give an estimate of the flight distance of the signal from the beacon to the receiver [15, 16]. Neburka et al. [17-19], after extensively analyzing the performance of BLE technology in indoor environments, show that it is a promising technique for indoor positioning, even though the RSSI values are inaccurate and highly dependent on the BLE module used. Its new abilities, such as durability, mobility and high reaction time, have led to Bluetooth BLE technology replacing Wi-Fi for positioning purposes.

There also exist some infrastructures or device-based localization technologies as well. The former use WLAN, UWB (Ultra-Wide Band), RFID (Radio Frequency Identification) and IR (Infrared) technologies, while the latter employ the inertial sensors of mobile devices such as accelerometers or gyroscopes [20-22].

The WLAN-based systems normally measure the distance based on the wireless signal strength or TOF (Time of Flight) in the network. The UWB-based systems use a wireless technology that transmits a large amount of digital data through a wide-spectrum frequency band. This consumes relatively more power than Bluetooth system and costs more but has lesser background noise and wider transmission distance [21-25]. Meanwhile, the RFID-based system uses a technology that identifies objects or people by using radio frequencies. This may not be able to locate indoor positions accurately but can determine their proximity. Finally, IR-based system employs a technology that estimates the position by obtaining the 3D-depth information by using TOF (infrared) with a IR-Depth camera. A 3D map can be produced by mapping the depth information onto the 2D image taken with a regular camera.

Scientific novelty of the research. In the course of the experiment, it has been revealed that applying methods of filtering and data smoothing to the RSSI data of a Bluetooth beacon allows to achieve an acceptable accuracy of location determination.

In addition, it is obvious that RSSI measurements are not perfect, and many previous projects either hide these inaccuracies by redundancy, or adapt the system to the specific environment in which it will be deployed.

In contrast to well-known approaches, the use of methods of filtering and data smoothing makes it possible to increase the accuracy of positioning in the internal positioning system.

## 3. INDOOR NAVIGATION METHODS

Indoor navigation can be provided by the following methods:

– Wi-Fi navigation;
– Geomagnetic positioning;
– Satellite navigation systems + Inertial navigation systems;
– GSM based navigation;
– Bluetooth beacons;

### *Wi-Fi*

Navigation by Wi-Fi points is based on already existing indoor infrastructure. It operates as follows:

* user device scans available Wi-Fi access points;
* the acquired data are transmitted to server;
* using the data on locations of Wi-Fi access points, the server analyzes and displays information about current position;
* the user coordinates are displayed on the device.

When available access points are applied, the positioning error can reach 25 m. These targets can be aided by special Wi-Fi infrastructure, however, it is rather expensive. Moreover, there exist some difficulties with identification of devices connected to the networks concerning subsequent mapping of customer motions. For instance, starting from iOS 8, mac-addresses of Apple devices (iPhone, iPad) constantly vary aiming at elimination of advertising activity.

### *Geomagnetic positioning*

This method is based on orientation by earth magnetic field using geomagnetic abnormalities as criteria of geomagnetic positioning. For practical application of this method, it is required to fix geomagnetic abnormalities on locality where orientation should be performed and then to plot them on the map. Then, the navigation is performed by device equipped with magnetometer. This is exemplified by IndoorAtlas system developed by experts of Oulu university. It is characterized by high complexity of implementation and provides imperfect navigation results. The accuracy depends on various magnetic fields of indoor objects. For instance, electrical wiring and mobile devices have their magnetic fields which affect final data.

*Satellite navigation systems and inertial navigation systems*

This method is based on periodical receiving of signal from satellite navigation systems. For instance, upon entering tunnel, the device stores the last received satellite data and then, on the basis of smartphone data from accelerometer, gyroscope, magnetometer, assumed route is plotted. It is obvious that the accuracy of geopositioning is strongly impaired.

*GSM navigation systems*

At least one base GSM station is located in the visibility range of mobile phone/GSM modem, as a rule, there are several stations. Their coordinates are known and quite often are fixed (except for mobile base stations). Due to various services presenting data on base stations in the visibility range, it is possible to obtain identifiers, and on their basis to obtain information about their location and then, using triangulation, to obtain approximate current coordinates. The disadvantage of this method is low accuracy of final geopositioning.

*Bluetooth beacons*

This method will be used in this work upon development of indoor navigation system. It provides sufficient accuracy allowing to determine the number of storey where the user is located. Herewith, the involved expenses are moderate.

## 4. DEVELOPMENT OF MODEL WITH BLUETOOTH RSSI

This section describes positioning by conversion of RSSI from Bluetooth beacon at distance. RSSI is a measurement of the power present in a received radio signal. This is used for determination of distance to the point of signal transmittance.

Bluetooth is the commercial standard for wireless personal networks. It is mainly intended for consumption of low-energy and short-range activity among several mobile devices. Since this communication protocol is based on RF, no line of vision is required between the communication devices. Bluetooth controls communications and data exchange between devices in the immediate vicinity and not requiring for high traffic capacity and data communication channels. Contrary to Wi-Fi networks based on Ethernet, detection of surrounding Bluetooth devices and available services is more simple, thus allowing for simplified communication between paired devices.

Nowadays, smartphones apply Bluetooth as preferred communication method for data exchange and accessories connection. Numerous PC accessories, including mouse, keyboards, headsets, and printers are based on Bluetooth standard for wireless communication. Wide range of Bluetooth profiles provides basis for development of wide scale soft- and hardware applications. Since the number of devices with Bluetooth support increases, detection and connection of these devices is highly important.

The existing Bluetooth stack provides simple interface for users to detect surrounding Bluetooth devices and their available services. However, the interface does not present any relevant information about the distance to these surrounding devices. Numerous soft- and hardware applications can use this supplemental information about distance. For instance, social network and other application can use locating utility for presentation of spatial maps of other users in the network for social communication. In networks with increased safety level, spatial comparison of devices can be used for detection of malicious users or unknown devices on corporate wireless network. Bluetooth Triangulator is intended for presentation of positioning data so that these high-level applications could be implemented.

As in other flowcharts of wireless locator, the level of transmitted signal can be used for detection of mobile unit positioning. Using several readings of this signal level in three or more various spatial points can be used for forecasting of accurate positioning of mobile unit. In the case of Bluetooth protocol, the indication of received signal (RSSI) is the measurement of level of received signal. For wireless network device, RSSI is usually used as reference for detection of the most optimum communication energy required for certain communication line. This value (in dB) can be obtained upon request of surrounding device or communication with already connected device.

### 4.1 Restrictions and problems to be solved in the research

Detection of Bluetooth does not guarantee detection of all surrounding devices even if a device is located in the range. According to the published specification, Bluetooth applies frequency hopping and toggles channels frame to frame. In order to detect surrounding Bluetooth devices, detector transmits respective message via several channels during detection period. Even though the detection period takes about 10 s by default, a neighboring device can omit detection message listening to it at other channel or missing it in due time. As a consequence, the neighboring device does not response to detection message. In order to solve this problem, we can perform detection several times or to increase the detection period so that to decrease probability of the fact that any Bluetooth device in the range is not detected.

RSSI is a numerical indicator of signal strength received by wireless receiver, its unit of measurement is dBm [26-32]. In this work RSSI is used for determination of distance, wireless communication is performed by Bluetooth 4.0. Since the wireless signals become weaker proportionally to covered distances, then it is possible to detect certain distance using a model of path loss.

In general, wireless signals are characterized by three negative properties: signal attenuation, signal interferences, and multipath propagation. Attenuation occurs when electromagnetic radiation becomes weaker when the signals pass obstacles. This phenomenon also takes place in vacuum. Therefore, the strength of wireless signal is inversely proportional to the distance between transmitter and receiver. This is referred to path loss. Signal interferences are attributed to the phenomenon when transmitted data cannot be obtained by receiver due to interferences between wireless signals transmitted with identical frequency band. Finally, multipath propagation refers to the phenomenon when wireless signals reach the receiver individually via several paths at various distances when they collide with some objects [33].

In this work we try to measure distance between transmitter and receiver using the model of path loss. In an ideal room, without signal breaking objects, it is possible to state that the first received signal covered direct path between two devices. However, in fact, signals reach final destination points via longer routes after collision with furniture or motions of humans in the room. Taking this into account, we placed beacons on the ceiling. Since the measurements acquired by indoor localization are always somewhat erroneous due to multipath propagation, we attempt to decrease errors by determining center of gravity (COG) of each candidate location as the final location.

Bluetooth has been selected as wireless communication technology because it is less expensive and required for low energy consumption. Bluetooth 4.0 consumes significantly less energy in comparison with other versions, this method with low energy consumption is referred to as BLE [28-32].

### 4.2 Determination of distance using RSSI

The only variable to determine the distance to transmitter is RSSI.

RSSI as a function distance is determined by the Friis transmission formula as follows [23]:

$$P_d = P_0 - 10 \cdot n \cdot \lg(\frac{d}{d_0}) \qquad (1)$$

where: $P_d$ is the RSSI (dBm); $P_0$ is the signal strength measured at the distance; $n$ is the coefficient of signal strength loss as a function of existence of obstacles; $d$ is the distance to beacon, $d_0$ is the calibration distance at which the power $P0$ was measured.

The signal attenuation constant n is determined experimentally, the signal level can be presented by RSSI.

Therefore, the distance is predicted as follows:

$$d = d_0 \cdot 10^{\frac{P_0 - P_d}{10 \cdot n}} \qquad (2)$$

*Table 1. Attenuation constants measured in experimental environment*

| Distance (m) | N | RSSI (dBm) |
|---|---|---|
| 1 | - | 44 |
| 2 | 3.322 | 62 |
| 3 | 4.610 | 74 |

### 4.3 Determination of coordinates by trilateration

The determined distance presents information about the distance to the point of detection in one measurement but does not provide full object positioning. The distance between initial point and target object is determined by circle with the center in initial point (or sphere: in the case of three measurements). Our object can be located in any point of this circle.

Therefore, in order to detect object positioning in 2D or 3D space, it is required to know more than only distance. Most frequently the object positioning is determined by measuring distance to the object from at least three points. This method is known as trilateration. If the distance to the object is measured from two points, then we obtain two possible points where the object can be located in plane (Fig. 2).

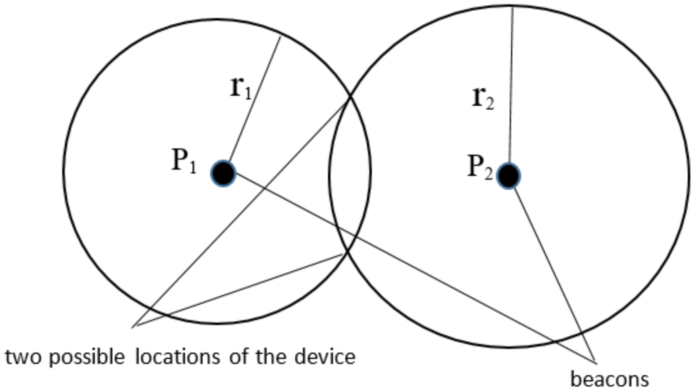

*Figure 2. Positioning By Two Beacons*

Adding the third distance, we obtain the third circle and accurate object positioning at the intersection of all three circles. Similar positioning method known as triangulation is based on two points with known positions. The object positioning is determined using the angles of triangle formed by these points and the detected point.

Figure 3 illustrates the intersection point (x, y) when the central points (P1, P2, P3) of the three circles and the radii (r1, r2, r3) are already known [21].

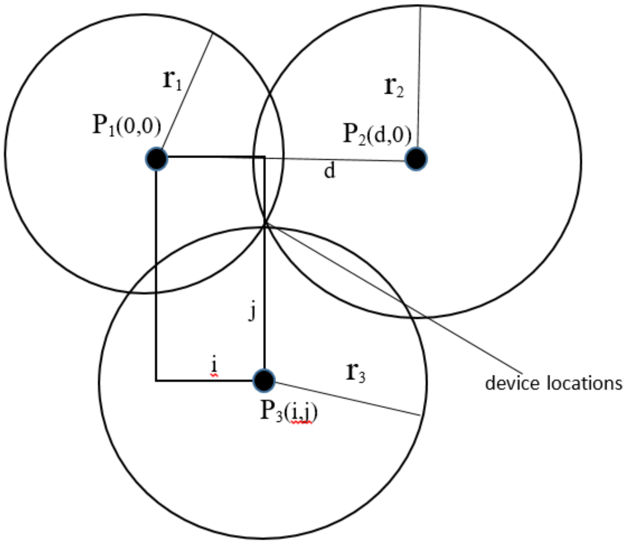

*Figure. 3. Positioning By Trilateration*

The following equations represent three circles in Fig. 2.

$$r_1^2 = x^2 + y^2$$

$$r_2^2 = (x-d)^2 + y^2 \qquad (3)$$

$$r_3^2 = (x-i)^2 + (y-j)^2$$

While combining these equations, we determined the intersection point (x, y), since the positioning beacons were located on the ceiling in order to minimize interferences upon signal propagation and to eliminate them in the plane where user device existed.

During trilateration the number of intersecting points should be higher than one in the case of two and more circles or spheres. That is, the condition d - r 1 < r 2 < d + r 1 should be valid.

Another problem is in inaccuracies related with RSSI readings, RSSI measurements can vary significantly for a given mobile device even if it is steady. Environmental conditions and physical objects (both temporal and constant) can create interferences for ceiling based on RF and can result in erroneous RSSI. The most frequent error source is the effect of multiple signal reflection (Fig. 4).

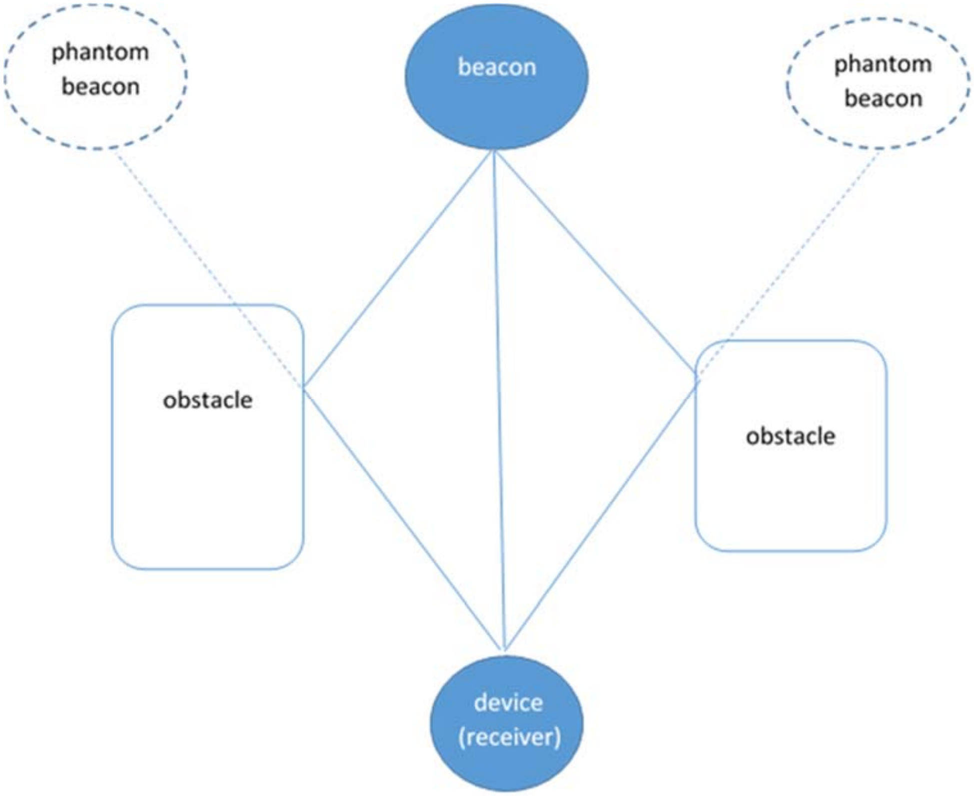

*Figure 4. Multiple Signal Reflection*

Propagating radio waves are reflected from obstacles. Therefore, in the case of large obstacle, the receiver can obtain several signals from the nearest beacon. The reflected waves generate phantom signals which are recognized by receiver as real. Therefore, the receiver cannot detect accurate distance to beacon, this impairs received signals and results in errors of receiver positioning.

The reflected radio waves generate the effect of phantom beacons which are recognized by receiver as real. This results in prediction errors based on signal strength.

The system ignores RSSI of certain signal when trilateration condition is not met.

## 5. IMPLEMENTATION

The experiments were carried out in a room with the sizes of 9×11 m. The data were acquired by measurements in nine points of the experimental site. Figure 5 illustrates the points of measurements. The mark moves subsequently to each point where navigation data are read in one minute.

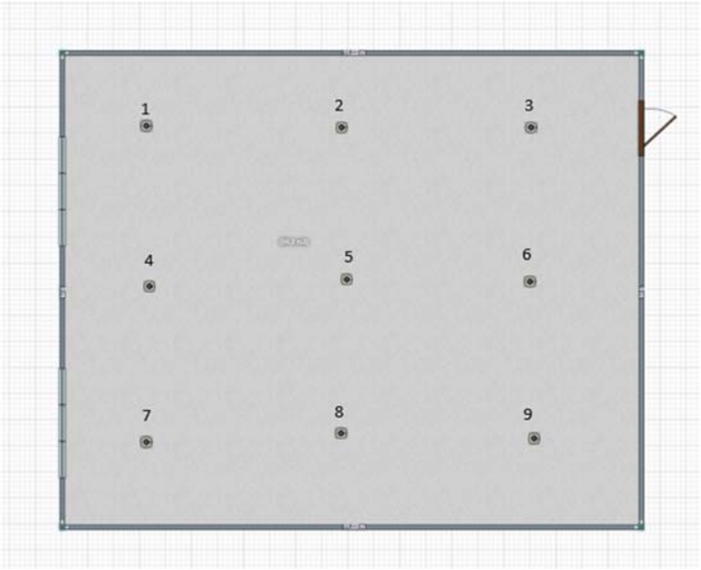

*Figure 5. Location Of Points In Experimental Site*

### 5.1 Determination of distance

The distance was determined by Eq. (2). The only variable is RSSI obtained by scanning BLE devices. However, it is initially required to determine calibration RSSI (signal level measured at calibration distance) and coefficient of signal strength loss.

Since the received signal is unstable even at small distances, the calibration RSSI was set to averaged results acquired in 45 s (Fig. 6). About 100 packets are transmitted in 45 s at the frequency of 450 ms. Average value based on this data is –49.3. This parameter can be measured for each beacon separately, if external sources effect with different intensity in different places of building.

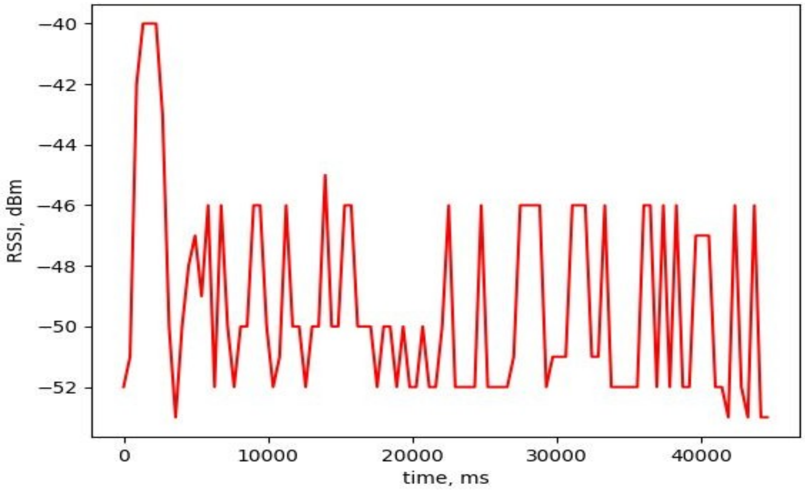

*Figure 6. RSSI At The Distance Of 1 M*

Since the calibration RSSI transmitted by beacon cannot be fractional, it is rounded to –49.

The coefficient of signal strength loss depends on noises and obstacles (including humans) between beacon and signal receiver, hence, it can be different for different rooms. At this stage the coefficient was predicted by RSSI measurements at the distance of 3 m (Fig. 7) and 5 m (Fig. 8) from the beacon. Isolating the required coefficient from Eq. (1), we obtain the following:

$$n = \frac{P_0 - P_d}{10 \cdot \lg(\frac{d}{d_0})}$$

The coefficient is determined by substitution of all known data. Signal level is determined by averaged data as in the case with calibration RSSI.

The calculated coefficients equaled to 2.44 for 3 m and 2.56 for 5 m. Taking into account nonstability of data the coefficient was set to 2.5.

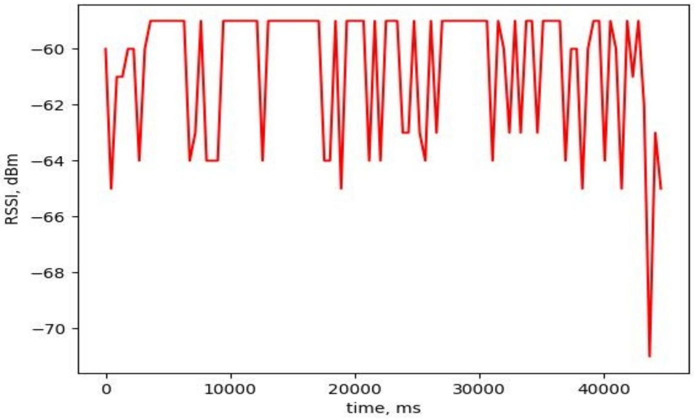

*Figure 7. RSSI At The Distance Of 3 M*

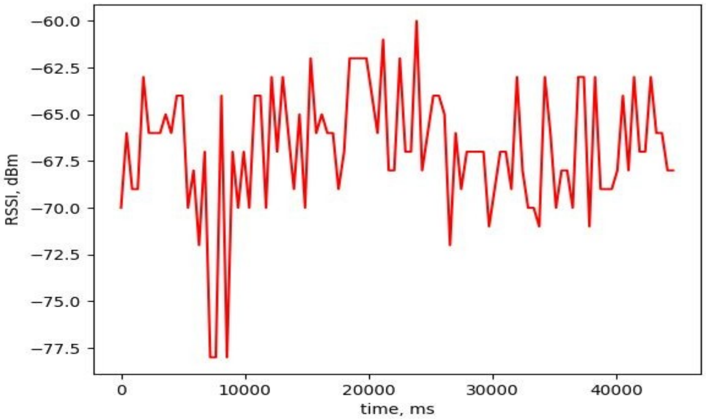

*Figure 8. RSSI At The Distance Of 5 M*

As in the case with calibration RSSI, coefficient of signal strength loss can be calculated separately for various room points, however, this would require for development of supplemental structure, such as imprint map, for data storage.

Root-mean square deviation (RMSD) is calculated by the obtained navigation data. The obtained data are summarized in Table 2.

*Table 2. RMSD in different points*

| # | RMS, m. |
|---|---|
| Point 1 | 0.006986 |
| Point 2 | 0.003713 |
| Point 3 | 0.014417 |
| Point 4 | 0.079708 |
| Point 5 | 0.008515 |
| Point 6 | 0.003689 |
| Point 7 | 0.006555 |
| Point 8 | 0.017849 |
| Point 9 | 0.008850 |

The data in Table 2 are illustrated in Fig. 9.

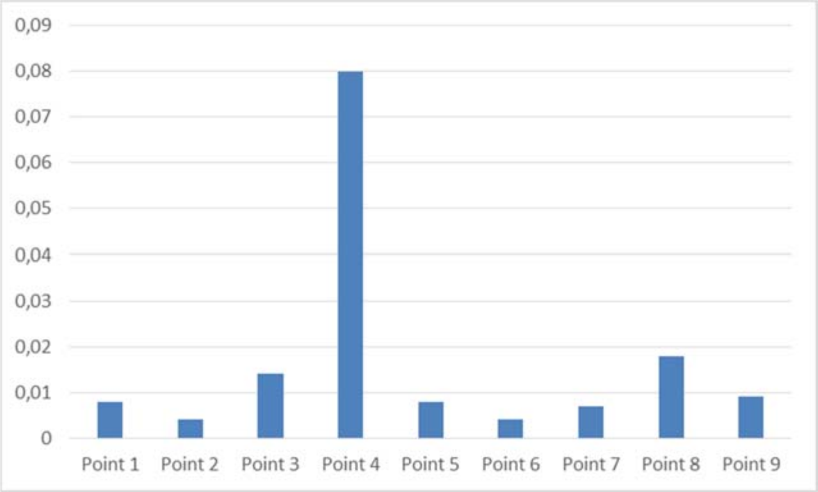

*Figure 9. RMSD In Different Points*

It follows from Fig. 9 that the highest RMSD is observed in point 4 which is attributed to RTLS operation. Figure 10 illustrates readings of navigation system in point 4.

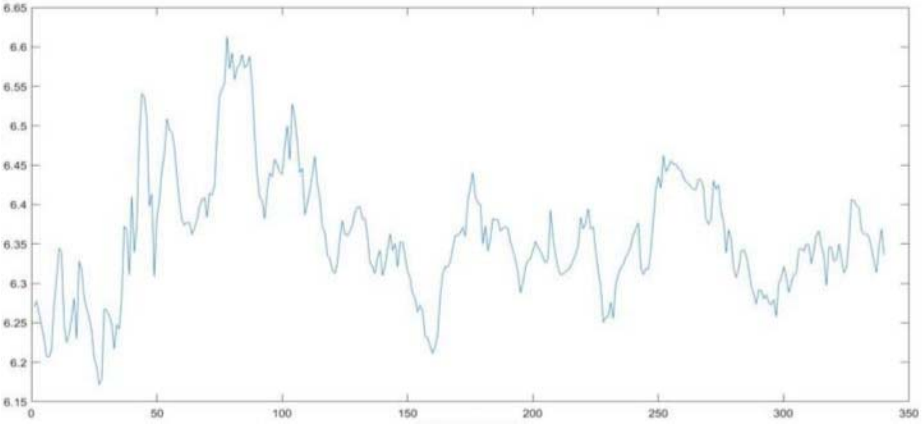

*Figure 10. Measurements In Point 4*

It can be seen in Figs. 9 and 10 that the RMSD of position detection reaches 8 cm, absolute errors can be as high as 25 cm. The mentioned errors are significant for the considered experimental site, hence, the navigation accuracy is supported by filters.

It can be observed that the signal levels received by mobile device vary significantly even at its steady position. The data can be smoothed by moving average method based on data received per certain time interval, for instance 1 s, or on the basis of certain constant amount of last results. While configuring beacons, it should be mentioned that data transmission at higher frequency would improve accuracy upon smoothing, however, it can shorten significantly the battery operation lifetime. The optimum interval of packet transmittance was set to 450 ms. About three packets would be received by mobile device in 1 s with such interval.

Figures 11–13 illustrate smoothing results (blue line) by various types of RSSI moving average (red line) obtained upon moving mobile device similar to measurements in Fig. 10.

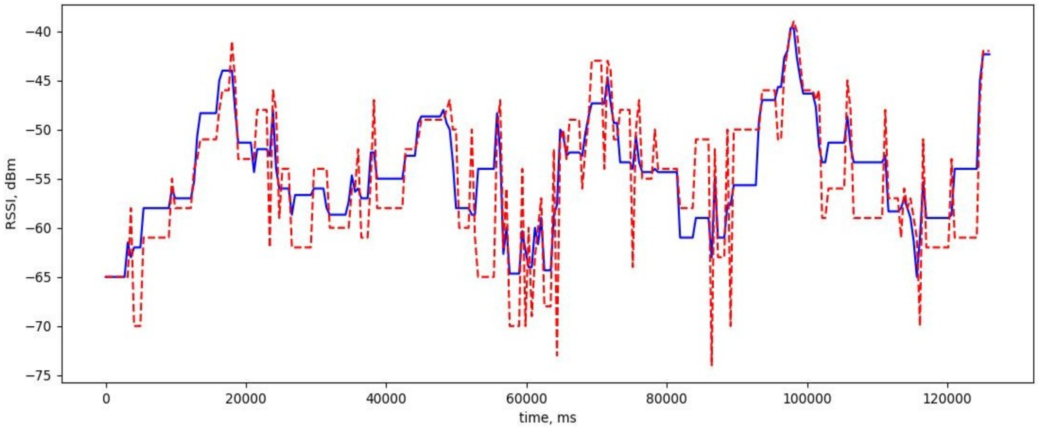

*Figure 11. Simple moving average*

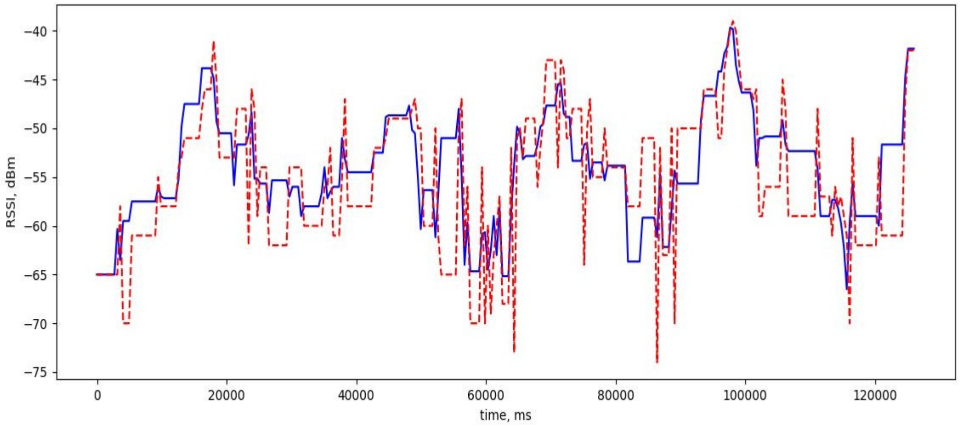

*Figure 12. Linearly weighted moving average*

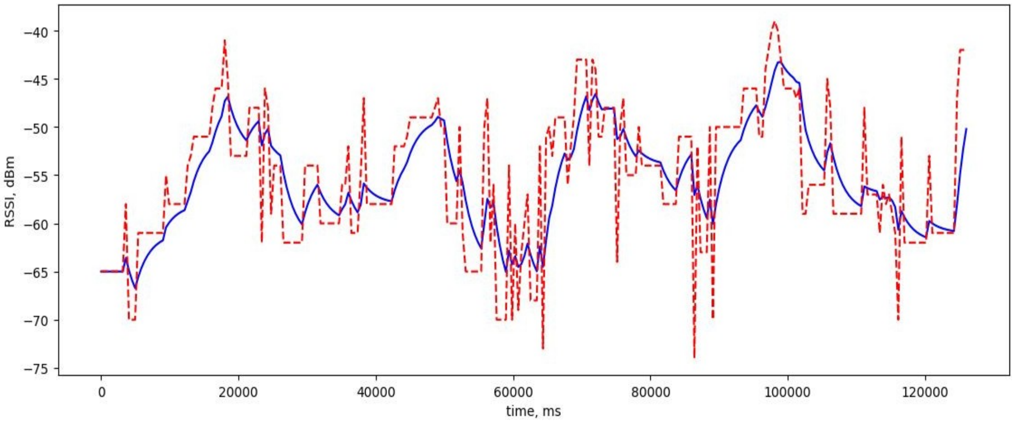

*Figure 13. Exponentially Weighted Moving Average*

## 6. CONCLUSION

It has been proved that applying methods of smoothing to beacon data improves the positioning accuracy, and it has been revealed that exponential smoothing provides the best result in comparison with other variants.

Another method of improvement is the Kalman filter at the stage of coordinate predictions. It requires for information of motion pattern from inertial sensors, such as accelerometer, gyroscope, and magnetometer, installed in mobile devices.

Unfortunately, development of fully featured navigation system for mobile devices is a very difficult and labor consuming problem, it is not presented in this work. Without motion pattern, the Kalman filter becomes similar to smoothing by exponentially weighted moving average and, generally, cannot be applied because it is beyond the Kalman concept.

It is planned to improve the service, to enhance the measurement accuracy, and to expand the functionality. The involved error can be decreased by development of navigation system on the basis of inertial sensors installed in modern mobile devices.

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