Low-Power Intelligent Displaying System with Indoor Mobile Location Capability

Marius Vochin[1(✉)], Alexandru Vulpe[1], Ioana Marcu[1], and George Suciu[2]

[1] University POLITEHNICA of Bucharest, Sector 6, Bucharest, Romania
marius.vochin@upb.ro
[2] Beia Consult International, Bucharest, Romania

Abstract. Modern buildings require different IT facilities, therefore integrated communication services have become a must. Although there are already commercial products on the market, most of them need well trained operators, while others require manual and time-consuming operations. The present paper introduces an intelligent displaying and alerting system (SICIAD), implemented over a communication infrastructure with support for wireless ePaper and iBeacon technologies to enhance displaying static and dynamic information, as well as to ease the indoor orientation of guests using smartphones. An Android mobile application is developed which enables indoor user location and guidance. Possible beneficiaries of such systems are educational and research institutions due to remote authentication support in research facilities through Eduroam technology. The paper gives functional validation and performance evaluation aspects are presented for the indoor positioning component of the proposed system.

Keywords: ePaper · iBeacon · Alerting system · Indoor positioning · Low power display

1 Introduction

Nowadays, the need for an intelligent, integrated, sustainable and easily managed system for digital and up-to-date room signage for offices, meeting rooms and conferences has an increase importance for modern public and office buildings. The emergence of Internet of Things (IoT) and digital interactions using electronic paper (ePaper) [1, 2] technology has marked a new phase of technological innovation in this direction. Important advantages are also brought by iBeacon [3] technology, which relies on the Bluetooth Low Energy (BLE) standard to create stationary constellations of low-power beacons which can be used to determine the indoor position of mobile terminals or signaling points of interest.

This work is part of the SICIAD [4, 5, 6] research project which proposes an intelligent displaying and alerting system that relies on wireless ePaper and iBeacon technologies from LANCOM to create custom displays for both static and dynamic information, as well as to ease the indoor orientation of guests.

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In this paper, the iBeacon capabilities of the SICIAD system are investigated in respect to indoor advertising, guidance and location.

The paper is organized as follows: in Sect. 2 we present the mobile device positioning system, Sect. 3 contains detailed experimental validation scenarios, while Sect. 4 outlines the conclusions.

2 Mobile Positioning System

A mobile application was developed for Android system which enables the user to detect its location based on the availability of Wi-Fi and iBeacon (BLE based radio packets) signal presence. The main functionalities of this software module are to capture BLE packets, to extract location relevant information and to process them in order to display notification or alerts related to current status and user position. The application functional validation was performed on a commodity hardware such as LG K8 mobile phone with BLE 4.2 support and Android 6.0 operating system.

The application tests if the device is Bluetooth enabled, whether the adapter is turned on, if multiple Bluetooth notifications are allowed, and whether access to the current location of the phone is allowed. As the instructions are parsed, a checkup is made to see if the permissions have been granted, and the user is asked to allow access. If all the conditions are met, the necessary processes are created, and the application continues to function. If something is missing, a corresponding error message will be displayed, and the application will stop.

The list of retrieved devices is presented with details (name, address, time since the last occurrence, current and average Received Signal Strength Indicator (RSSI) level, relative distance estimation, RSSI mediated levels, and details display button). Only details about the rooms where LANCOM devices with iBeacon capabilities are located are shown; other received BLEs beacons are displayed by the app, but as no details are known about their location or configuration, only a general message will be displayed if the user selects them. These unknown devices can be filtered before adding them to the list, resulting in faster application performance (no need to process their data).

Different measurements were conducted on the access points in the University Politehnica of Bucharest (UPB) campus, which is a reinforced concrete building, with 30 cm thick walls. The location chosen to test the positioning solution is on the 3rd floor of Building A from Faculty of Electronics, Telecommunications and Information Technology, Bucharest, which is an area with offices and laboratories, as shown in Fig. 1. Commodity hardware has been used at the BLE receiver part, such as SM-G361F, G930FD smartphones, and also a HP ENVY x360 laptop. Three Lancom access points with integrated iBeacon transmitters were installed, one LN-830 E [7] model and two L-151E [8]. They were scheduled to periodically emit BLE advertising beacons to be visible to mobile devices, and a maximum power lever was choosen from three available levels.

Lancom iBeacon has been factory calibrated to provide three power levels at a distance of 1 m: high (−52 dBm), medium (−58 dBm), and low (−75 dBm) of the broadcasted beacon message, which allows an approximation of the distance between the access point and BLE receiver. For beacon broadcasting dedicated frequencies can

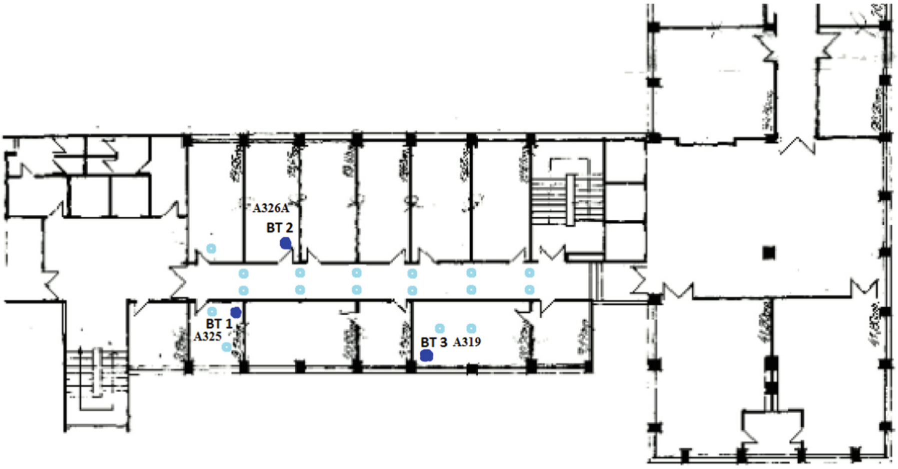

Fig. 1. Testbed location plan

be used: 2402 MHz, 2426 MHz, and 2480 MHz. With our off-the-shelf smartphone, the measurements at reception indicate −40, −46, −62 dBm, at a distance of several cm of the antenna.

3 Experimental Evaluation

It has been concluded from the measurements that a −10dBm attenuation is induced by a campus wall placed between the sender and receiver BLE device. Therefore, by setting the access point emission power at the lowest level and having one beacon in each room we would accurately provide room signage capability.

Each router used a unique MAC physical address, and different major and minor beacon values were set allowing the packets to be differentiated according to their source.

In the lobby, the points of measurement are aligned along two straight lines parallel to the hall walls. These two straight lines are 0.5 m from the nearest hallway, and within a distance of one meter. Along each straight line there were six measuring points, which represent a total of twelve locations. To calculate the distance between the router and the mobile terminal at each of these points, a simple Pythagoras' theorem for rectangular triangles was used.

The corresponding colors in Fig. 2 are: green for "x" - the measured average values of the RSSI, red for the maximum values obtained and blue for the minimum values corresponding to the respective distance between the terminal and each of the three access points. Thus, there can be observed the variation and distribution of values for each location. There can be noticed quite large variations, although the transmitter and the receiver were fixed during the measurements. These variations occur because the radio signal reaches the receiver on several paths that have different lengths and are attenuated due to passing through various objects or by the reflection of radio waves.

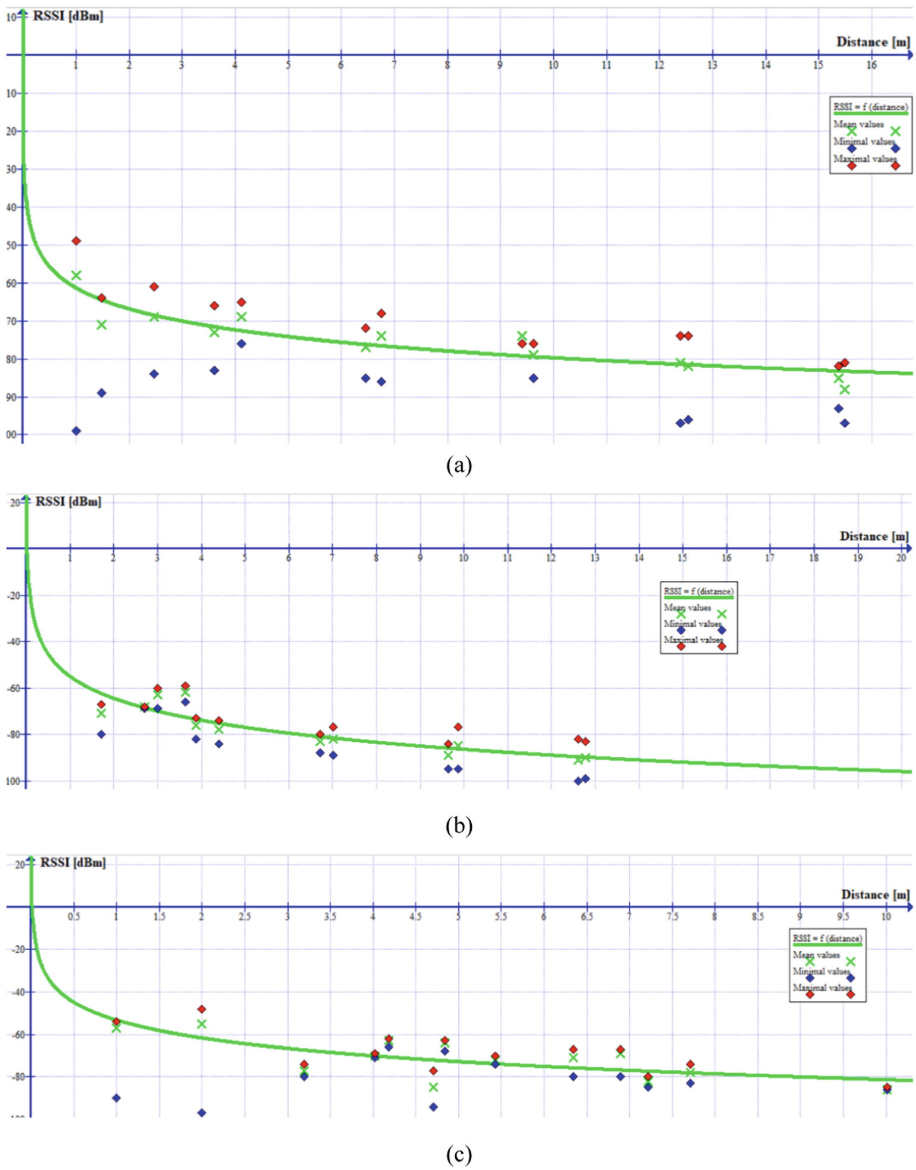

Fig. 2. Variation of RSSI with distance increasing for (a) AP1, (b) AP2 and (c) AP3 (Color figure online)

With green, curves were plotted considering the average values of the RSSI. They have different characteristics, being influenced by the walls through which the signals have been propagated. Their descriptive mathematical formulas are shown below:

$$F1(x) = -8.04738496 * \ln(x) - 61.27611836$$

Distance variation of the reception power level for AP1 transmitter.

$$F2(x) = -13.73284621 * \ln(x) - 54.99489558$$

Distance variation of the reception power level for AP2 transmitter.

$$F3(x) = -12.23482004 * \ln(x) - 53.26174039$$

Distance variation of the reception power level for AP3 transmitter.

It can be noted that each function is different from the other. In addition, they depend on the placement of objects in the building. Table 1 illustrates how good the approximations were with the actual measured values.

Table 1. Comparison between estimated and measured values for access point (a) AP1, (b) AP2 and (c) AP3

Distance [m]	Computed RSSI [dBm]	Measured RSSI [dBm]	Error [dBm]	Mean error [dBm]
(a)				
1	−61.28	−58	3.28	2.45
1.48	−64.43	−71	6.57	
2.47	−68.55	−69	0.45	
3.6	−71.58	−73	1.42	
4.11	−72.65	−69	3.65	
6.46	−76.29	−77	0.71	
6.76	−76.65	−74	2.65	
9.41	−79.32	−74	5.32	
9.62	−79.49	−79	0.49	
12.39	−81.53	−81	0.53	
12.54	−81.63	−82	0.37	
15.37	−83.26	−85	1.74	
15.49	−83.33	−88	4.67	

(*continued*)

Table 1. (*continued*)

Distance [m]	Computed RSSI [dBm]	Measured RSSI [dBm]	Error [dBm]	Mean error [dBm]
(b)				
1.72	−62.44	−71	8.56	3.31
2.7	−68.64	−68	0.64	
3	−70.08	−63	7.08	
3.64	−72.74	−62	10.74	
3.87	−73.58	−76	2.42	
4.39	−75.31	−78	2.69	
6.71	−81.14	−83	1.86	
7.02	−81.76	−82	0.24	
9.64	−86.11	−89	2.89	
9.86	−86.42	−85	1.42	
12.61	−89.8	−91	1.2	
12.78	−89.98	−90	0.02	
(c)				
1	−53.26	−57	3.74	5.47
2	−61.74	−55	6.74	
3.19	−67.45	−77	9.55	
4.02	−70.28	−70	0.28	
4.18	−70.76	−63	7.76	
4.71	−72.22	−85	12.78	
4.84	−72.56	−64	8.56	
5.43	−73.96	−72	1.96	
6.34	−75.86	−71	4.86	
6.89	−76.88	−69	7.88	
7.22	−77.45	−82	4.55	
7.71	−78.25	−78	0.25	
10.01	−81.45	−86	4.55	
10.37	−81.88	−85	3.12	

4 Conclusions

The system presented in this work implements an integrated communication infrastructure which offers dynamic display capabilities using the ePaper technology, as well as enables indoor location-based services such as visitor guidance and alerting using iBeacon-compatible mobile devices.

Being based on the BLE standard, iBeacon technology can potentially operate with almost all off the shelf smart mobile terminals, providing a cost-effective solution for an indoor positioning system. In combination with a smartphone application and a wireless communication system, BLE can enable advertising and distribution of location-based content.

In order to maintain real-life relevance of achieved data, commodity hardware was chosen to be used in test scenarios. A professional mobile BLE receiver was considered in order to improve indoor location awareness precision, but this would question relevance of data obtained in the context of commercial and industrial applicability.

While the iBeacon emitters integrated in the used Wireless access points can enable location-based services, accurately determining each users' location may require additional, battery-powered BLE beacons. Such a network (or constellation) of beacons could provide a more performant indoor guidance system, due to its effectiveness at a range of several meters (compared to several centimeters for NFC tags). Moreover, although the investment in Beacon devices may be significant, the already widespread use of compatible smart devices may reduce the necessity of other hand-held devices.

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