Universal System for Indoor Location

Richard Boťanský, Michal Hodoň, Lukáš Čechovič, Peter Ševčík

***Abstract*—** The aim of this paper was to make an application which can provide indoor localization. The application is made from three components: iBeacons, Raspberry Pi and web server. Result consists of two web applications. First web application runs on Raspberry Pi, which communicates with iBeacons through Bluetooth. Second web application runs on web server, which communicates with Raspberry Pi.

***Keywords*—** indoor localization, communication through Bluetooth, iBeacon, Raspberry Pi, Flask application, web application.

I. Introduction

Indoor localization has emerged as a critical technology in various domains, including logistics, smart buildings, healthcare, and retail. Unlike outdoor localization systems such as GPS, which rely on satellite signals, indoor environments present unique challenges, including signal attenuation, multipath interference, and the presence of physical obstacles such as walls and furniture. These limitations necessitate the adoption of alternative localization technologies specifically designed for indoor use [1], [2]. Bluetooth Low Energy (BLE) technology, introduced with Bluetooth 4.0, has gained significant attention as a promising solution for indoor localization due to its low power consumption, cost-effectiveness, and compatibility with a wide range of devices [3]. Among BLE-based solutions, iBeacons—developed by Apple Inc.—stand out for their simplicity and widespread adoption. iBeacons transmit unique identifiers that can be processed by receiving devices, enabling proximity detection and relative localization [4], [5]. In this study, we propose a system that leverages iBeacon technology, Raspberry Pi devices, and a web server to create an efficient and scalable indoor localization framework. The Raspberry Pi acts as a receiver, capturing BLE signals from iBeacons, while the web server processes and visualizes the data in real-time. By addressing the limitations of existing systems and integrating robust hardware and software components, this system aims to offer a reliable solution for tracking objects and personnel in indoor spaces. The motivation for this work stems from the increasing demand for precise indoor localization systems in industries where real-time tracking can enhance operational efficiency and user experience. From tracking assets in warehouses to enabling navigation in large public buildings, the potential applications of indoor localization are vast and diverse [6], [7]. This paper details the design, development, and evaluation of the proposed system. It discusses the selection of hardware and software components, the methodology for signal processing and communication, and the results obtained from experimental testing. The integration of Internet of Things (IoT) devices into daily life offers significant opportunities for reducing energy wastage and enhancing sustainability. Among these innovations, smart sockets stand out for their ability to provide real-time insights and control over energy consumption. This paper explores the conceptualization, design, and practical implementation of a smart socket tailored to address the growing demand for smarter, more energy-efficient homes.

II. Integration

The methodology for the indoor localization system was developed to integrate hardware, software, and calibration processes into a cohesive and reliable solution. The system utilized

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iBeacons as BLE transmitters, broadcasting unique identifiers and RSSI values. These transmitters were strategically positioned to ensure coverage across the designated indoor space. Signals from the iBeacons were received by Raspberry Pi devices configured with Bluetooth adapters and programmed using Python scripts. The Raspberry Pi devices processed the received signals and estimated distances using calibrated RSSI-distance models. Signal processing involved filtering techniques to minimize noise and mitigate the effects of multipath interference, ensuring the accuracy of distance estimations. The Raspberry Pi devices also hosted lightweight web servers built using Flask, enabling data communication with a central server over a local network. Standard TCP/IP protocols facilitated this communication, ensuring seamless data transfer. The central server was developed using CakePHP for backend processing and Vue.js for frontend visualization. It aggregated data from multiple Raspberry Pi devices and maintained a MySQL database for storing real-time and historical localization data. The server used this data to compute object locations through algorithms such as trilateration or centroid-based methods. A user-friendly web-based dashboard provided access to localization data, offering features such as movement tracking, zone-based analysis, and visual representations of object positions. The calibration process was a fundamental part of the methodology, aimed at establishing reliable correlations between RSSI values and physical distances. Signal strength data was collected at defined distances, and filtering techniques were applied to refine this data by reducing noise and environmental interference. Calibration data was iteratively refined to ensure consistency and accuracy, enabling the system to perform effectively across varying indoor conditions. The system architecture comprised three layers. The sensing layer collected BLE signals from iBeacons, the processing layer handled signal refinement and data communication via the Raspberry Pi devices, and the visualization layer presented the processed data through the web dashboard. This structured approach allowed for the efficient integration and management of system components, ensuring that the system met the operational requirements of indoor localization in diverse application areas.

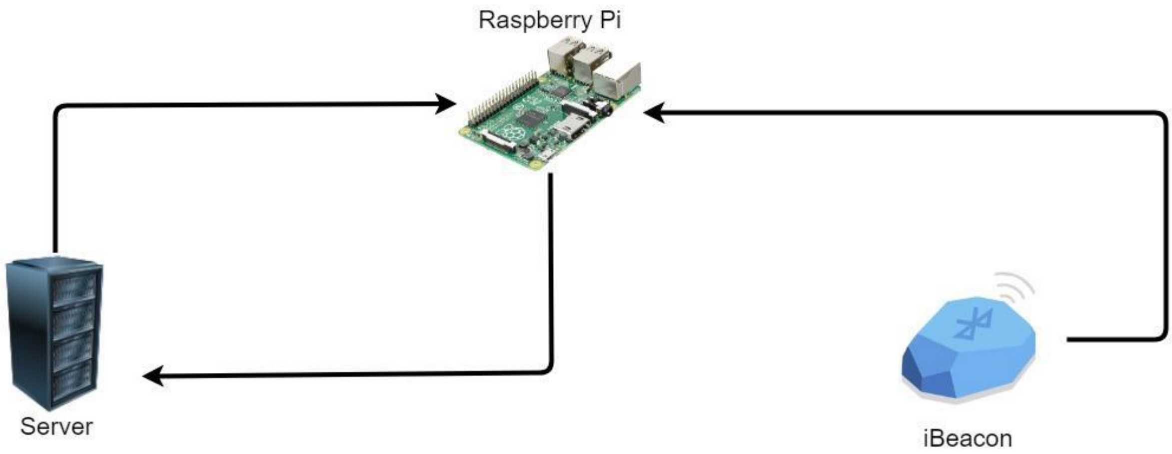

Fig. 1 System block schematic

calibration_beacons	
PK	id
	name
	value

nearby_beacons	
PK	id
	name
	type
	time

last_updates	
PK	id
	time
	name_table
	value

Fig. 2 RPi Database

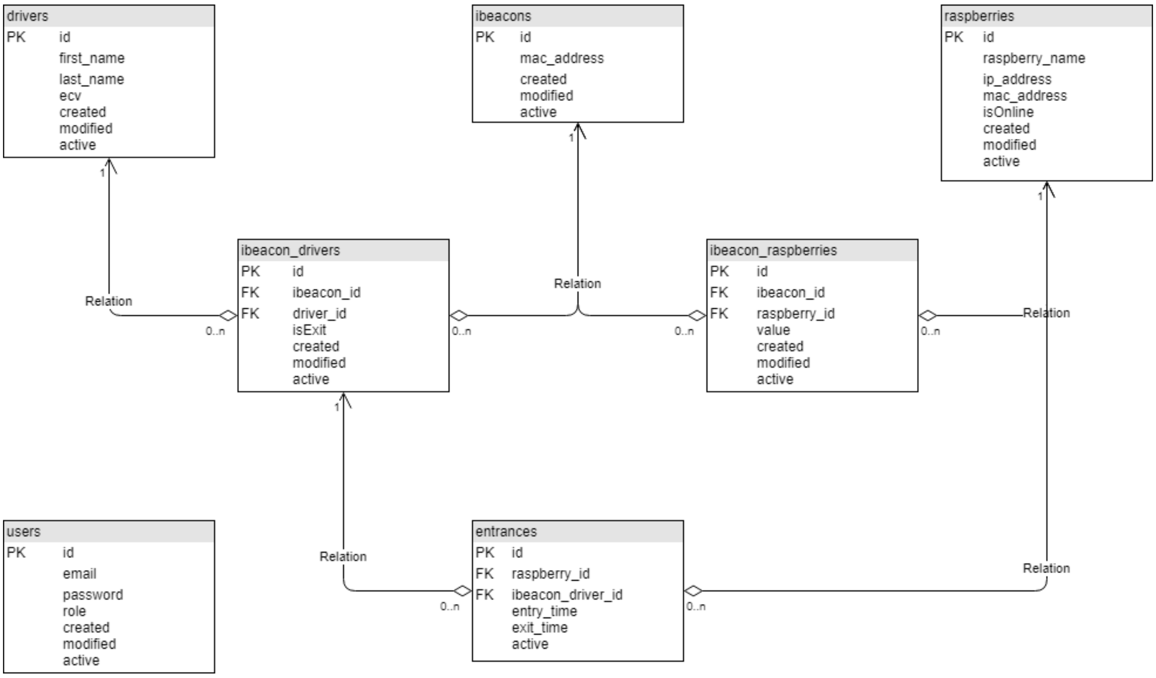

Fig. 3 Web application database schematic

III. Conclusion

The developed system was tested in a controlled environment with multiple iBeacons placed at known locations. Raspberry Pi devices accurately captured BLE signals and transmitted data to the web server. Calibration routines improved the precision of distance measurements. The web interface successfully displayed real-time localization data, showcasing the system's potential in practical applications. The proposed system demonstrated a high degree of accuracy in indoor localization tasks. However, signal attenuation due to physical obstructions such as walls and human bodies posed challenges in certain scenarios. The choice of iBeacons and BLE technology proved cost-effective and scalable. Future work could focus on integrating machine learning algorithms to enhance accuracy and exploring additional applications in healthcare and retail. This study successfully implemented an indoor localization system using iBeacon technology, Raspberry Pi devices, and a web server. The system offers a cost-effective and scalable solution for indoor localization, with potential applications across various industries. Future enhancements could include optimizing signal processing algorithms and expanding the system's functionality.

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