SKÚMANIE KVALITY SILY SIGNÁLU VZHĽADOM NA VZDIALENOSŤ KOMPONENTOV TRASOVACIEHO SYSTÉMU V UZATVORENOM PRIESTORE

INVESTIGATING THE QUALITY OF THE SIGNAL STRENGTH WITH CONSIDERATION OF THE DISTANCE OF THE COMPONENTS OF THE TRACKING SYSTEM IN A CONFINED SPACE

Ing. Erika Skýpalová

University of Žilina, Faculty of Securtiy Engineering, Department of Security Management, Univerzitná 8215/1, 010 26 Žilina, Slovakia
skypalova@uniza.sk

ABSTRAKT

Určovanie polohy osôb a entít vo vonkajšom prostredí je dobre známe prostredníctvom technológie Globálneho pozičného systému. V súčasnosti je však problematika určovania polohy výzvou aj vo vnútornom prostredí, ktoré sa vyznačuje prítomnosťou veľkého počtu osôb v čase prevádzky a na zvýšenie bezpečnosti alebo optimalizáciu procesov je potrebné monitorovať pohyb a polohu osôb. Okrem pohybu osôb je možné monitorovať aj polohu zariadení alebo materiálov, čo umožňuje určiť ich dostupnosť, a tým zvýšiť efektívnosť prevádzky. Technológia GPS však nie je vhodná pre potreby sledovania pohybu osôb a entít vo vnútornom prostredí z dôvodu nepriepustnosti signálov cez stavebné konštrukcie. Existuje však niekoľko technológií, ktoré umožňujú lokalizáciu osôb a entít vo vnútornom prostredí, ako napríklad Wi-Fi, Bluetooth, rádiofrekvenčná identifikácia, ultraširoké pásmo alebo technológie na báze infračerveného žiarenia. Článok sa zameriava na skúmanie vplyvu vzdialenosti beaconov na kvalitu sily prijímaného signálu.

Kľúčové slová: trasovací systém, Bluetooth beacon, nízkoenergetická technológia Bluetooth, indikátor sily prijatého signálu.

ABSTRACT

Positioning of persons and entities is well known in the outdoor environment through Global Positioning System technology. However, nowadays, the issue of positioning is also a challenge in indoor environments, which are characterised by the presence of a high number of people at the time of operation, and to increase safety or optimise processes, the movement and position of people needs to be monitored. In addition to the movement of people, it is also possible to monitor the location of equipment or materials, which makes it possible to determine their availability and thus increase operational efficiency. However, GPS technology is not suitable for the needs of tracking the movement of people and entities in indoor environments due to the impermeability of signals through building structures. However, there are several technologies that allow the location of people and entities in indoor environments, such as Wi-Fi, Bluetooth, RFID, Ultrawideband or IR. The article focuses on investigating the effect of beacon distance on the quality of received signal strength.

Keywords: tracking system, Bluetooth beacon, Bluetooth Low Energy, Received Signal Strength Indicator.

INTRODUCTION

Tracking systems are a set of multiple technologies that allow tracking of different objects or persons. Currently, there are several technologies designed to create location tracking systems, including:

- Geographic Information Systems (GIS),
- Global Positioning System (GPS),
- Radio Frequency Identification (RFID),
- Near Field Communication (NFC),
- QR codes,
- WiFi,
- Bluetooth Low Energy beacon technology (BLE) [1].

The selected tracking system is based on Bluetooth Low Energy beacon technology. The beacons have been tested in confined space conditions. Bluetooth Low Energy was developed in 2011 and was originally designated as Bluetooth 4.0. Compared to conventional Bluetooth, BLE provides an improved data rate of 24 Mbps and a coverage range of 70 to 100 m with higher energy efficiency. BLE has the ability to connect in a very short time, typically a few milliseconds. It then goes into sleep mode until the connection resumes, resulting in low power consumption. This feature makes it possible to be powered by a single battery, which can have a lifespan of up to 5 years. Compared to WiFi placed near electrical outlets, beacons with their own batteries can be distributed in arbitrary locations indoors [2].

Bluetooth beacons are small wireless devices that communicate via BLE technology in the 2.4 GHz frequency band. They transmit signals at regular intervals with a certain power, without the need for pairing with receiving devices. Beacons can have sensors that send measured data related to environmental parameters such as pressure, temperature and others. This information can be received by any devices in range equipped with a Bluetooth module [3], [4].

Received Signal Strength Indicator (RSSI) is one of the simplest and widely used approaches for indoor positioning. RSSI represents the actual power output of the received signal. It is usually measured in decibel-milliwatts (dBm). The RSSI value can be used to estimate the distance between the transmitting and receiving device. The higher the RSSI value, the smaller the distance between the transmitting and receiving device [5], [6].

1 IBEACON PROTOCOL

iBeacon uses a BLE-based localization technique for the purpose of determining the location of objects, where the distance is computed based on the Bluetooth signal transmission and the received signal strength indicator RSSI [7], [8].

The BLE data format contains 4 main pieces of information, namely UUID, Major, Minor and Tx-power. UUID (Universally Unique Identifier) is a 16-byte string that is used to distinguish different iBeacon devices. When iBeacons are placed in a commercial chain, the terminal is able to recognize the chain to which the devices belong. Major represents a 2-byte string used to determine the specific ownership of the devices. If a store chain has five iBeacon devices, all these devices have the same Major number. The Minor is characterized as a special identifier for each device or object. iBeacon has a different Minor for each object. Tx-power is defined as the signal strength exactly 1 m from the device, which can be used to judge the wireless signal distance between the iBeacon device and the terminal. However, in an actual measurement application, the measured values of the iBeacon wireless signal range are not completely accurate. This is due to changes and fluctuations in the wireless signal or environmental factors and other characteristics [9].

Currently, beacon-based person tracking is implemented in many industries. BLE technology is suitable for indoor positioning, which makes it of great importance for various organizations or operations. Through a smartphone and the corresponding mobile app, it is possible to interact with the beacons. In this paper, the results of testing a tracking system based on iBeacon technology, which is formed by the beacons EEK-N and FSC-BP103 in a confined space, are interpreted. Experimental testing has been carried out to detect the effect of beacon spacing on the value of the received RSSI signal due to changing conditions in a given environment.

2 METHODOLOGY

The FSC-BP103B and EEK-N beacons were tested in terms of received signal strength, represented by the RSSI value. A Raspberry Pi Zero 2 W microcomputer with Raspbian operating system was used for testing. This is a Linux distribution based on Debian. The microcomputer has WiFi, Bluetooth and micro HDMI reduction to the monitor. The data storage is an SD card and it is powered via micro USB 5 V, 2 A is recommended. The system is powered via an external charger.

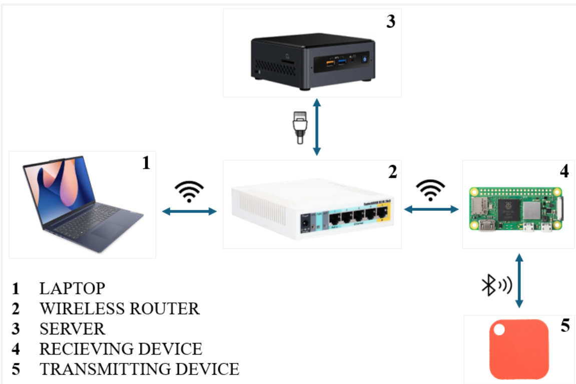

Fig. 1 Diagram of the communication among the components of the tracking system

The aim of the testing was to investigate the effect of beacon spacing on the RSSI value. Last but not least, an significant aspect is that the experimental testing was carried out under confined space conditions. The first step was to prepare all the tools and devices needed to perform the tests. Subsequently, the conditions for carrying out the individual tests were created. A microcomputer at a height of 1.8 m was placed in the centre of the room to represent the receiving device. A WiFi router was used to establish a wireless connection over the local network to the IP address of the microcomputer, on which software was installed to allow access to beacon-related data, including the RSSI value. Subsequently, 3 circles with a radius of 0.5 m, 1 m and 2 m were created around the microcomputer, on which the transition points were marked. Clockwise transitions were performed along the marked points on the circles, and the RSSI values of the two beacons were measured at each point and at a specific time. For the height of the microcomputer installation, transitions were made along all the circles created. While performing the transitions along the marked points on the circles, the beacon EEK-N was held in the right hand and the beacon FSC-BP103B was held in the left hand, and their direct visibility was ensured.

Fig. 2 Receiving device, transmitting device and external power supply

3 RESULTS

Since the beacons are constantly transmitting signals, several RSSI values were displayed in real time on the IP address of the microcomputer. As a result, the arithmetic mean of the 5 RSSI values for the two beacons at each point of the circle was calculated.

When the microcomputer was installed at a height of 1.8 m, passes were made along 3 circles with radii of 0.5 m, 1 m and 2 m. The circle with a radius of 0.5 m contained 16 points. The 1 m and 2 m circles contained 24 points.

Table 1 interprets the maximum, minimum, and average RSSI values of the beacons at an installation height of 1.8 m for the receiving device and at distances of 0.5 m, 1 m, and 2 m, respectively.

Table 1. RSSI values at distances of 0.5 m, 1 m and 2 m for a microcomputer installation height of 1.8 m

RSSI [dBm]	HEIGHT 1,8 m					
	Distance [m]					
	0,5		1		2	
	EEK-N	FSC-BP103B	EEK-N	FSC-BP103B	EEK-N	FSC-BP103B
Maximum	-43	-52	-40	-52	-41	-56
Minimum	-72	-74	-70	-77	-66	-85
Average	-52	-62	-52	-63	-57	-70

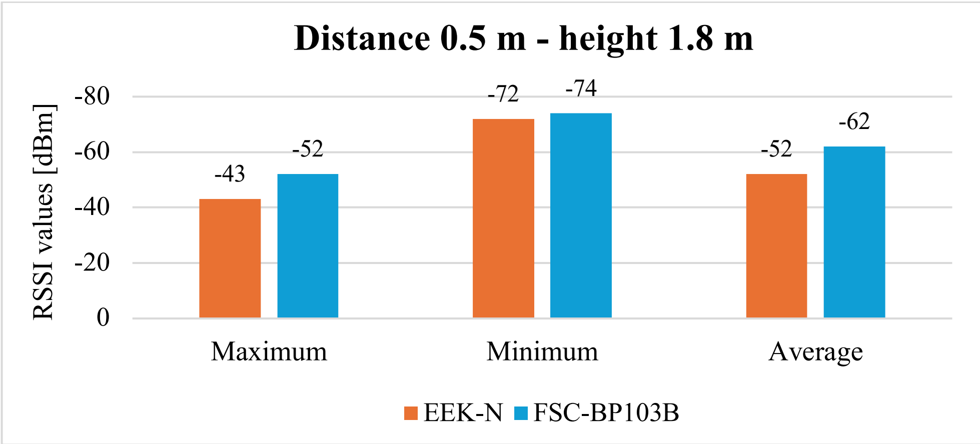

Fig. 3 RSSI values at distance of 0.5 m and height 1.8 m

In Fig. 3, the RSSI values of the individual beacons at a distance of 0.5 m are interpreted for an installation height of the receiving device of 1.8 m. At a distance of 0.5 m, the EEK-N beacon reached a **maximum RSSI** value of **-43 dBm.** The **minimum RSSI** value is **-72 dBm** and the **average value** is **-52 dBm.**

Based on the values in Fig. 3, it can be concluded that the FSC-BP103B beacon achieved lower RSSI values compared to the EEK-N beacon. The **maximum RSSI** value decreased by **-9 dBm,** the **minimum value** decreased by **-2 dBm,** and there was a decrease of **-10 dBm** for the **average RSSI value.** This indicates that the signal quality of the FSC-BP103B beacon is lower at a distance of 0.5 m from the receiving device compared to the signal quality of the EEK-N beacon.

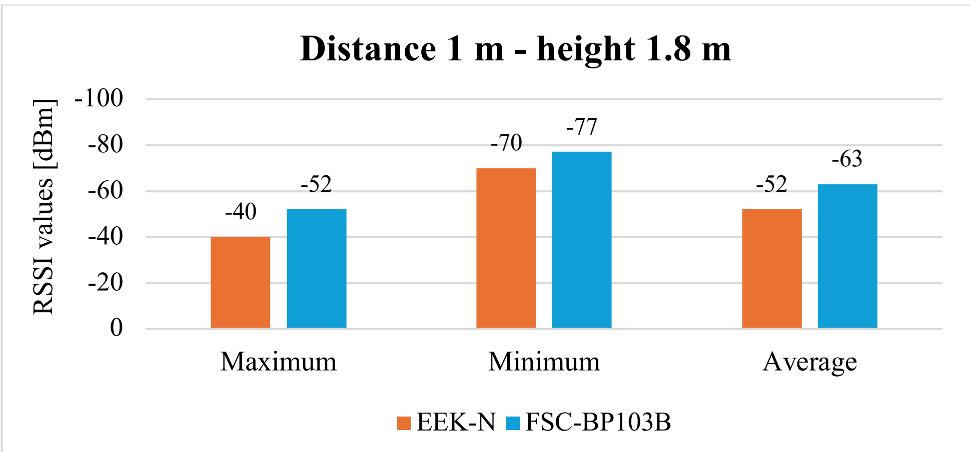

Fig. 4 RSSI values at distance of 1 m and height 1.8 m

For transitions at points 1 m away from the microcomputer, a **maximum RSSI** value of **-40 dBm** was recorded for the beacon EEK-N. The beacon reached a **minimum value** of **-70 dBm** and the **average value** is **-52 dBm.**

The FSC-BP103B beacon achieved lower RSSI values even at 1 m distance compared to the EEK-N beacon. The **maximum value** decreased by **-12 dBm,** the **minimum value** by **-7 dBm** and the **average value** by **-11 dBm.** Compared to the results in Fig. 3 at a distance of 0.5 m, there was a slight decrease in the average RSSI value.

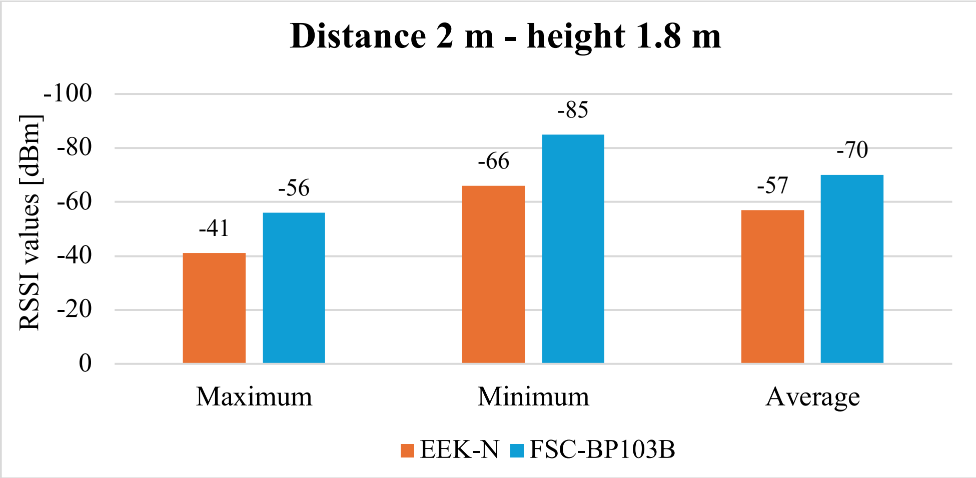

Fig. 5 RSSI values at distance of 2 m and height 1.8 m

At a distance of 2 m, the beacon EEK-N reached a **maximum RSSI** value of **-41 dBm,** a **minimum value** of **-66 dBm,** and the **average value** across all transition points is **-57 dBm.** Compared to the previous average values in Fig. 3 and Fig. 4, there was a decrease of **-5 dBm.**

The FSC-BP103B beacon repeatedly achieved lower RSSI values than the EEK-N beacon. The **maximum value** decreased by **-15 dBm,** the **minimum value** by **-19 dBm** and the **average value** is lower by **-13 dBm** compared to the beacon EEK-N. Based on the comparison with the results in Fig. 3 and Fig. 4, it can be concluded that at a distance of 2 m from the microcomputer, the largest differences in the decrease in the average RSSI values of the two beacons occurred.

4 DISCUSSION

Although the distance of the beacons has an effect on the RSSI values, the receiving device was able to receive the signals emitted by the beacons at each specified distance and was also able to receive the signals at each marked point of the circles. Based on the results obtained, it can be concluded that the signal strength of the EEK-N beacon was greater compared to the transmitted signal of the FSC-BP103B beacon.

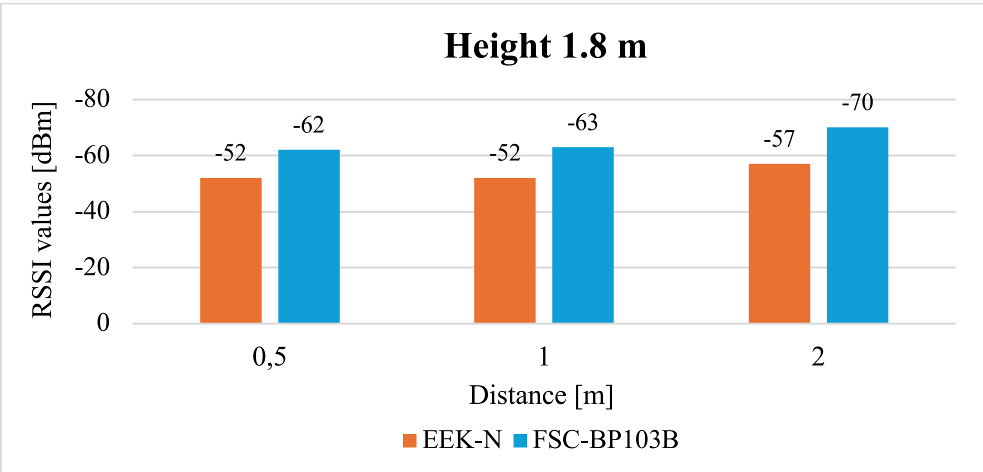

Fig. 6 Average RSSI values of beacons at a height of 1.8 m

The FSC-BP103B beacon achieved lower RSSI values, which could be due to the different receiving capability of the individual beacons. When designing a tracking system in confined space conditions, it is necessary to ensure sufficient coverage of the space by the receiving signal in order to eliminate environmental factors that negatively affect the quality of the signal strength and influence the propagation of the signal among the components. Environmental factors affecting propagation and signal quality include the presence of obstacles made of different materials, other devices in the space using radio frequencies for their functionality, or the height and distance of the individual components making up the tracking system. As a consequence of these environmental factors, absorption, diffraction or interference effects may occur which affect the propagation and quality of the signal.

5 CONCLUSION

In this paper, the effect of beacon distance on the quality of the received signal was investigated. Factors affecting the propagation of the signal transmitted by the beacons are an issue for the implementation of the tracking system. Through the performed tests, it has been shown that the quality of the received signal strength, characterized by the RSSI value, can be negatively affected by the distance of the beacons from the receiving device. It has been shown by testing that the greater the distance of the beacons from the receiving device, the lower the quality of the received signal strength. It is concluded that the accuracy of the resulting RSSI values obtained from the tests is affected by the use of only one receiving device. Thus, insufficient coverage of the area by the receiving signal may affect the positioning accuracy. Therefore, it is important to assess the conditions of the space, perform software calibration and then test the designed system for its functionality before the actual implementation of the system. The quality of the received signal strength may also be influenced by other factors such as the height of the receiving device location, obstacles existing in a particular space or building structures of objects. For this reason, further testing will be carried out in the future to investigate the reliability of the tracking system in specific confined space conditions in order to assess the various factors that could limit the propagation and quality of the signal.

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