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Bluetooth Based Indoor Navigation System

C. Uttraphan¹, F. Abdul Aziz¹, Mohd Helmy Abd Wahab¹, Syed Zulkarnain Syed Idrus²

¹Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia (UTHM)

²Faculty of Applied and Human Sciences, Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia

Abstract. The navigation system has been around for many years in terms of map and simple navigation control, and only recently has technology caught up in the idea of the interconnected world, allowing full assist of navigating from one point to another becomes reality. Recently, the architecture of the shopping stores is getting more and more complex and it is hard for the consumers to find their desired store. As the satellite signal cannot be used inside the building, hence, in this project, we propose an indoor navigation system by using the Bluetooth low energy (BLE) signal. The BLE signal is emitted from every BLE beacon in the building and the receiver which is the smartphone will determine which of the beacon is the closest to the receiver and determine the user location. This technique is called fingerprint which is usually used for BLE beacon. The verification tests have been performed in UTHM where the lecture hall complex was used for the test. The results show that the proposed system is able to navigate to the destination accurately.

1. Introduction

Nowadays every device that we encounter in real life has the ability to ease our daily life or better known as smart device, such as a smartphone. One of the features in the smart device is the navigation system. Navigation is a paramount system in assisting the user to navigate from point A to point B. Currently, there are two types of navigation system, which are outdoor and indoor navigation. However, only one of the navigation systems that is commonly used in Malaysia which is the outdoor navigation.

The outdoor navigation is a navigation technique which utilizes the satellite signal. Without the signal from the satellite, the navigation will not work properly as it highly dependent on the system called the Global Positioning System (GPS). However, the GPS is almost impossible to be used indoors as the signal cannot penetrate into the building. As the building such as shopping complex, hospital and airport are getting bigger, this can create a problem in finding a specific location, hence, a new technique of indoor navigation system needs to be introduced.

Bluetooth is a cheap device mainly used to transfer data or communicate with other devices. The recent technology from Bluetooth is called Bluetooth Low Energy (BLE) or the Bluetooth 4.0 measurements. This system has a long scan time, which is very suitable for this project in scanning big area. Therefore, an indoor navigation system can be developed by utilizing the Bluetooth 4.0. It can be used to locate the smartphone that is connected to the system by using the fingerprinting



system. Fingerprinting is a system where all of the BLE has a unique ID, thus, it can recognize the phone that is connected to it.

Even though the GPS is very useful to locate the exact location of a smart device with only small errors, but it still does not capable in navigation indoors as the satellite signal cannot penetrate into a thick wall. Indoor navigation is also important in these days as the building is getting bigger and complex, therefore, making it is almost impossible to find a specific location in a building without referring to the floor plan. Furthermore, time is wasted while moving into the building looking for a specific location or product. All of this can be solved with the introduction of an indoor navigation system that can track the user location in real time with a way finder to show the shortest route to the user. Instead of using satellite to pinpoint the user location, BLE will replace satellite and determine the user location.

In general, BLE Beacons will be placed within 10 to 100 m range in the building to create a large coverage of Bluetooth signals that can be received by the smartphones. As the smartphone moves into the Bluetooth signal area, the BLE will start to determine the location of the nearest BLE beacon. As the beacon identified the smartphone it will send a unique ID of the beacon and show the location of the smartphone in the phone application. Hence, showing the location of the smartphone in the building.

2. Related work

The navigation system has been introduced to public in 1990's and since then, it has been used on a daily basis [1]. However, indoor navigation system is sparse due to hardware limitation and cost. There are many techniques that can be used for indoor navigation, for example, Wi-Fi and the near field communication [1], but those are expensive and most importantly consume a lot of energy.

Bluetooth was developed in 1994 by Ericsson and the main purpose is to replace the wired communication as it is commonly used to transfer data [2]. The BLE is a low power alternative to the Bluetooth as the conventional Bluetooth need to be turned on for a long period of time to take advantage of its function [3]. With a low power device like a BLE, it can conserve a lot of resources while take its full potential to act as a transmitter of a receiver. The BLE has always been compared with NFC or RFID as they also offer almost the same technology with Bluetooth. However, Bluetooth has more functions and advantages compared to the other technologies.

There are a lot of related studies related to Bluetooth beacon such as the Indoor.rs [4]. It is one of the software company to study on indoor positioning and navigation technology using BLE beacons. Indoor.rs create a smartphone application that can guide the user to a specific area.

Other than Indoor rs there is also another service which is dedicated to indoor navigation called Wikibeacon.org [5]. The BLE beacon ID and the location are provided by the service from Wikibeacon.org. Wikibeacon also has its own iOS and Android applications dedicated for the beacon. Their beacons will be added onto the map as markers with information on their last known location. Wikibeacon can also help to generate universal unique identifier (UUID), Major and minor for a beacon. Therefore, they will be no double UUID and cause the beacon to collide with each other.

Before BLE beacon, the most of the previous works used classic Bluetooth positioning and the technique from proximity to trilateration and finally to fingerprinting. However, there are limitations in the classic Bluetooth. The time taken for the phone to scan for a nearby beacon is too long as it takes about 10s [5], hence, due to this limitation, the use of classic Bluetooth beacon is not popular.

The earliest approach for indoor navigation is by using wearable sensors [6]. The user needs to wear a specialize equipment which includes a display and sensors which help to gather all the necessary data. The sensors that are used for this system are the 3D accelerometer, 3D magnetometer, fluorescent light detector and temperature sensor.

One of the techniques that use a similar principle as the indoor navigation is the indoor positioning. Positioning is meant to locate and measure the location of the position. While, indoor navigation is more focus to the wayfinding. Aside from using a sensor, other studies show that an UltrawideBand (UWB) system is suitable for indoor positioning system [7]. UWB is a signal that is sent by the satellite where it will penetrate into the building and then supplied into a beacon that will spread the

radio signal throughout the building. The information can be received by tapping into the mast with the UWB radio.

Another interesting method of indoor positioning and navigation using a phone camera was proposed by [8]. The system consists of three steps in order to find the accurate position of the user. In the first step, a picture will be taken by the user and all the data will be analyzed compare with the database. When the image is identified, the actual position is deduced by comparing the image with the actual location in the database [9]. There are a few drawbacks of this technique as it can only locate the user without any navigation. Furthermore, it is going to be a hassle as there are a lot of the picture need to be taken to identify the location.

B. Han and L. Zhao [10] suggested to use a Wi-Fi as the main technology for the indoor positioning. The technique used in their system is similar our system as it also uses the fingerprinting. Their system also capable of outdoor navigation. A similar approach was proposed by S. Zehl [11] where the Wi-Fi beacon is tethered to the Wi-Fi and receiving information from the global server. Besides fingerprinting, there is another technique called Time and Angle of arrival. This technique also utilized the Wi-Fi for indoor navigation using a complex logarithm to achieve an accurate location [12]. The drawback is that Wi-Fi implementation is high cost and consume more energy [13].

Besides Wi-Fi and BLE, a magnetic map is another alternative for the indoor navigation [14], [15]. Inside the building there are iron, cobalt or nickel, these materials can help to create a magnetic field inside the building. The magnetic field on each place is unique after it have been identified. This will create a map for indoor navigation system.

As discussed above, the existing techniques are either high cost or consume a lot of energy. Therefore, the solution to the indoor navigation using BLE is the most feasible solution. This paper proposes a BLE based indoor navigation system. The proposed system utilizes the fingerprinting technique that can aid people to navigate inside a building without a satellite.

2.1 Bluetooth Low Energy Unit (BLE)

Bluetooth Low Energy or BLE is used to transmit or receive signals from or to other Bluetooth devices. The main advantage of BLE is that it consumes less energy as compared to its predecessor. BLE only consume 15mA at the peak transmit and 1 μ A during its sleep state. Also, the BLE itself is designed to send small packets of data so that it does not consume a lot of energy.

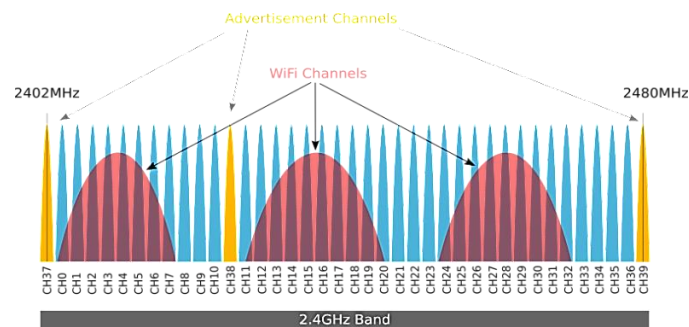


Figure 1. The Channel and Frequency for BLE

Figure 1 shows the channel and the frequency for a BLE. The BLE operate in 2MHz wide and has 40 channels. As the BLE only operated for a very short duration, it can definitely reduce the power consumption. The orange signal represents the advertising signals. In this channel, the Bluetooth will send the data to the receiver [16]. Considering, the main purpose of BLE is to cut costs, to reduce delay, and to increase the performance of positioning, BLE divides the advertising channles by reserving the dedicated advertising channels. This is because by using only one channel for advertising can cause massive contention on that channel.

The BLE advertisement signal follows a periodic protocol. Every advertising period beginning, each signal transmits its advertising message on every advertising channel. It will scan for listening devices. Due to many signals located at the same place, it may use the same advertising period size, where each signal randomly adds up to 10 μ s of jitter to every advertising period so that repeated collision can be avoided. If two signals have overlapping transmissions in an advertising period, the added jitter highly reduces the possibility of another collision. If the advertising message is small, this method avoids highly collisions in deployments of up to 200 or more signals [3].

2.2 Fingerprinting Technique

The name of the fingerprinting comes from the UUID in the beacon. The UUID will act as a fingerprint which can be differentiated and recognize. Other than that, Fingerprinting is also a process of developing a collection of discrete locations. As the user walks in area equip with beacons, the current signal strength based on the location of the beacon will be measured and compared to the database to determine the location of the user [20].

3. Methodology

Figure 2 shows the development process of the proposed system. It starts with the creation of the floor map of the targeted location. Next, four beacons will be placed in the location with the range between 70 m to 100 m each, as the maximum range of the beacon is 100 m. If the beacons are placed exceed the maximum range, there will be a zone that cannot be detected hence the fingerprinting technique cannot work properly. After the beacon location and the map have been developed, it is then be uploaded into the cloud so that the Android application can receive the data (beacon location and map).

The user interface of the application contains a login screen where the user can log in and access to the cloud. There will be also a location search feature in the application so that the user can find the location easily. After a location is selected, the location will be displayed in the application and ready for navigation.

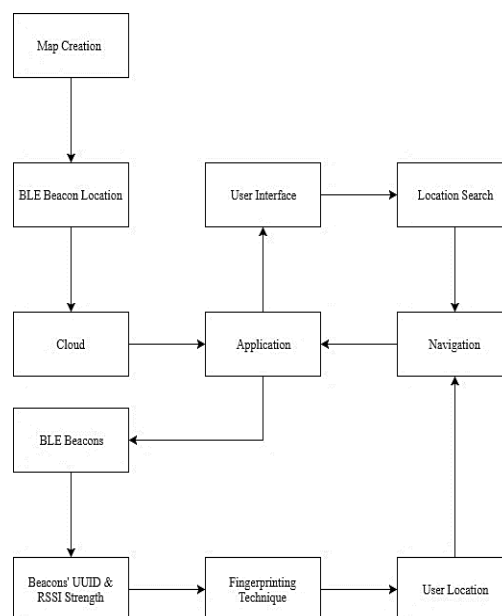


Figure 2. Block diagram of the proposed system

For the navigation to work, the application needs to be connected to the internet. The beacon main function is to send signals and not to receive any data from the smart phone. Each of the beacon has its own ID which will be used to identify which beacon is the nearest to the smartphone. The received signal strength indication (RSSI) is used to compare each of the beacon based on the distance of the beacon and the smartphone. The farther the smartphone from the beacon the lower the RSSI value, hence, the location of the beacon can be identified correctly. After the targeted location have been identified, the user location can be mapped and the navigation can be started.

3.1 Map Layout

The lecture hall complex in UTHM is selected for verification tests. The reason for this is to get as almost as the identical situation with a retail layout. Normally, in a retail building there will be a lot of shop lots with a wall dividing them, thus, by using the selected location for the tests, it can give an almost accurate result when applied it in a real situation

The map is created by using Java OpenStreetMap Editor (JOSM). The layout needs to be designed in 2D in order for JOSM application to decode and read the map. Each of the shop lots is named accordingly based on the shop location as shown in Figure 3.



Figure 3. 2-D layout of the building

3.2 Cloud Application

The cloud service used in the proposed system is from the Sail Cloud Solution. The Sail cloud service focuses on indoor navigation cloud. In the proposed system implemented in the Sail cloud, a new location is created called a “Shopping” where the floor map is added by drawing another layer of the map and be uploaded into the cloud. Then, the cloud will provide a unique ID for the user.

3.3 Beacon Placing and Fingerprinting

The optimum numbers of the BLE beacon is determined using equation (1) where R is the maximum radius for the beacon accuracy.

$$No\ of\ beacon = \frac{Area}{3.14 * R * R} \quad (1)$$

In the verification test, the area is about 3500 m² and the radius is set to 14 m (based on the RSSI reading), therefore the optimum number of beacon is six. The place selected is a row of classrooms where each of the classrooms will represent a shop lot. Thus, one beacon for each classroom and two beacons with about 14 m apart. Figure 4 shows the location of the beacons in the verification test.

After the beacon placement is done, the fingerprinting is ready to be set up and uploaded to the cloud. In order to record the fingerprinting signal, the application needs to be run and set the application to record the fingerprinting signal. During this procedure, the application will actively scan

all of the beacons in the area. The smartphone that runs the application needs to travel from one beacon to another. The reason for this is to get the reading of the RSSI signals. If the RSSI signal is high the application will determine that the smartphone is close to the beacon, hence, save the UUID. Then, when traveling to a place with two or more beacons, it will check the UUID and determine the closest beacon to it based on the RSSI signal. Once all of the beacons have been scanned, the application will be uploaded the data to the cloud and the main application is ready to be used as the fingerprinting record is completed.

4. Results

4.1 RSSI from Beacon

As mentioned in the previous section, if the RSSI signal is high, it indicates that the beacon is close to the beacon and vice versa. Thus, to test the capability of the BLE beacon for the proposed system, one beacon is placed at one point and the smartphone which will act as the receiver will be moved by 1 m and the reading of the RSSI is taken. From the reading value, the average value of RSSI is plotted versus distance. To make sure that the reading is accurate, the measurement is performed with (1) the beacon is placed without any wall from the receiver and (2) the beacon is placed within a wall between the beacon and the receiver.

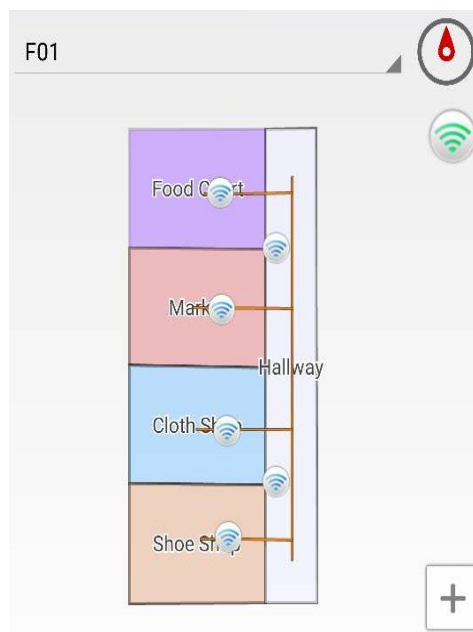


Figure 4. The location for the beacons

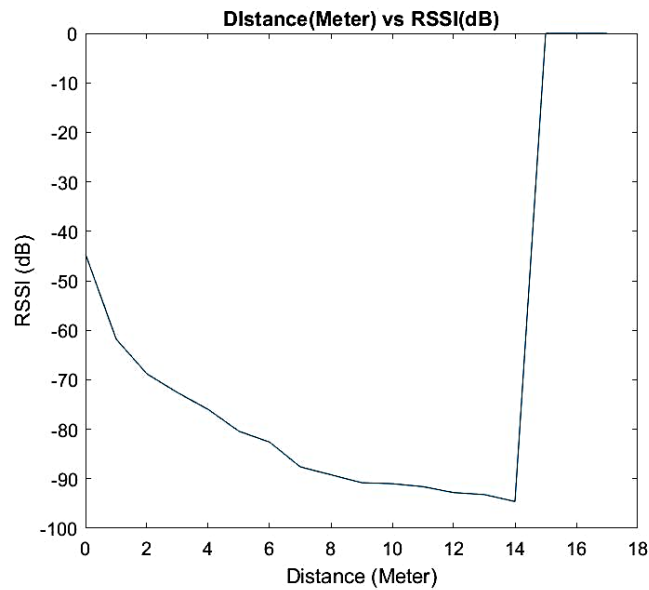


Figure 5. Distance (m) vs RSSI (dB) (without a wall)

From the plot in Figure 5, it proved that when the receiver is next to the beacon, the RSSI average value is -44.6 dB and when the beacon is 14 meters from the beacon the RSSI average value is -94.6 dB. However as soon as the receiver moves beyond 14 m, the connection between the receiver and the beacon is disconnected.

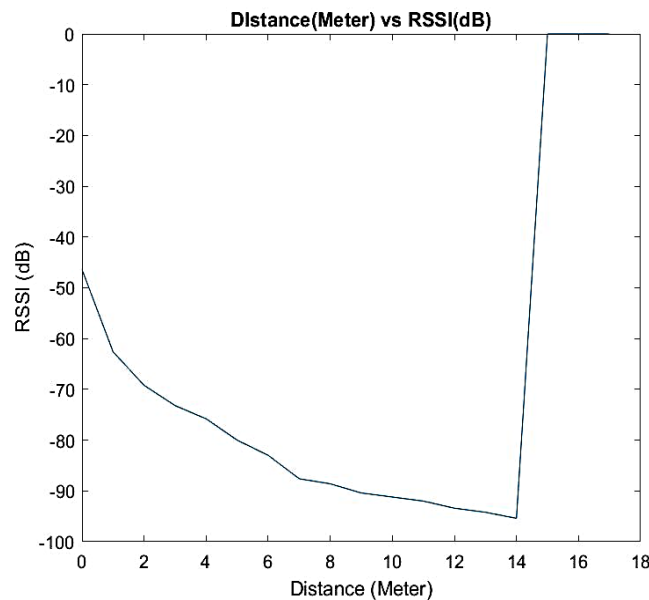


Figure 6. Distance (m) vs RSSI (dB) (with a wall)

For the test with a wall between the beacon and receiver, as shown in Figure 6, the result is identical to the previous test indicating that the signal not affected by the obstacles, suggesting that the proposed system can be used effectively in the complex buildings.

4.2 Indoor Navigation

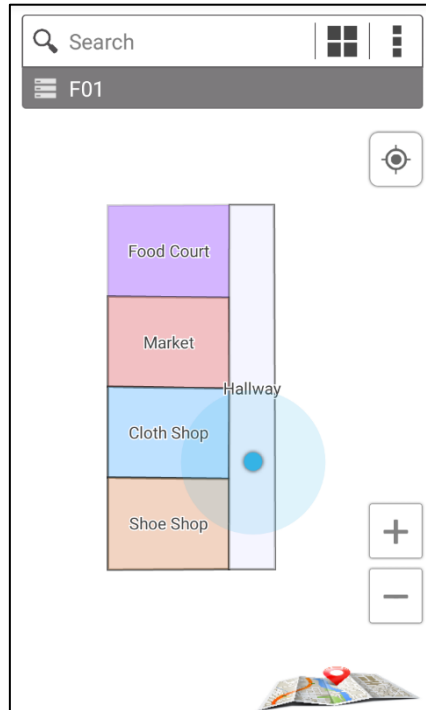


Figure 7. The blue dot on the map

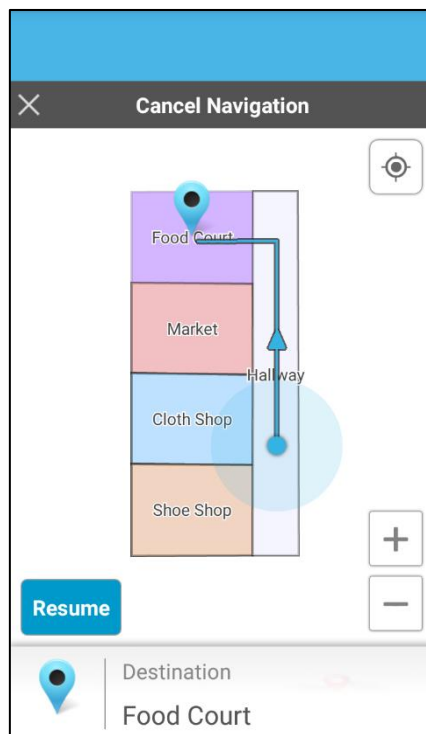


Figure 8. The wayfinding feature of the application

After that, the user can click at any desired location on the map. Once the location is selected and confirmed, the application will calculate the optimum route and shows it on the map just like in Google Map as shown in Figure 8. Thus, the user can navigate to the desired location in the shortest time. The smartphone will scan the whole area in order to get the correct signal from the BLE beacon. If there is a dead zone, which represent an area that the BLE signal cannot be reached, the blue dot will disappear and appear again once the smartphone enters a location which is covered by the BLE beacon signal.

Finally, when the user has reached the desire location, the application will show a message indicating that the user has reached the location.

5. Conclusion and Future Work

In this paper, we present an indoor navigation system using a BLE technology. The proposed system is successfully implemented. The verification test results proved that the proposed system is capable of performing indoor navigation with good accuracy. This system is very suitable for implementing in a large building such as shopping complex or airports as it is low cost and consume low energy.

For the future work, it is interesting to investigate the accuracy and the speed of the navigation algorithm, hence, proposed and an improved navigation algorithm. Also, the test size should be increased to investigate the reliability of the system.

References

- [1] A. Ozer and E. John, "Improving the Accuracy of Bluetooth Low Energy Indoor Positioning System Using Kalman Filtering," 2016.
- [2] N. K. J. Adkins, "Bluetooth LE 4.0 and 4.1 (BLE)," vol. 1, pp. 1–47, 2014.
- [3] A. F. H. Iii, V. Khanna, G. Tuncay, R. Want, and R. Kravets, "Bluetooth Low Energy in Dense IoT Environments," *IEEE Commun. Mag.*, vol. 54, no. 12, pp. 30–36, 2016.
- [4] B. Dong, T. Burgess, and H. B. Neuner, "Indoo.rs CaLibre - Unsupervised database free RSSI calibration indoor navigation," 2017 Eur. Navig. Conf. ENC 2017, pp. 198–205, 2017.
- [5] Wikibeacon, "About wikibeacon.org."
- [6] A. R. Golding and N. Lesh, "Indoor navigation using a diverse set of cheap, wearable sensors," *Dig. Pap. Third Int. Symp. Wearable Comput.*, pp. 29–36, 1999.
- [7] S. J. Ingram, D. Harmer, and M. Quinlan, "Ultra wide band indoor positioning systems and their use in emergencies," *Rec. - IEEE PLANS, Position Locat. Navig. Symp.*, pp. 706–715, 2004.
- [8] A. Mulloni, D. Wagner, I. Barakonyi, and D. Schmalstieg, "Indoor positioning and navigation with camera phones," *IEEE Pervasive Comput.*, vol. 8, no. 2, pp. 22–31, 2009.
- [9] M. Werner, M. Kessel, and C. Marouane, "Indoor Positioning Using Smartphone Camera," *Int. Conf. Indoor Position. Indoor Navig.*, pp. 1–6, 2011.
- [10] B. Han and L. Zhao, "An indoor positioning algorithm based on Wi-Fi fingerprint and inertial navigation system," pp. 6067–6072, 2017.
- [11] S. Zehl, N. Karowski, A. Zubow, and A. Wolisz, "LoWS: A complete Open Source solution for Wi-Fi beacon stuffing based Location-based Services," 2016 9th IFIP Wirel. Mob. Netw. Conf. WMNC 2016, pp. 25–32, 2016.
- [12] C. Yang and H. R. Shao, "WiFi-based indoor positioning," *IEEE Commun. Mag.*, vol. 53, no. 3, pp. 150–157, 2015.
- [13] V. Varshney, R. K. Goel, and M. A. Qadeer, "Indoor positioning system using Wi-Fi & Bluetooth Low Energy technology," 2016 Thirteenth. Int. Conf. Wirel. Opt. Commun. Networks, pp. 1–6, 2016.
- [14] B. Gozick, K. P. Subbu, R. Dantu, and T. Maeshiro, "Magnetic maps for indoor navigation," *IEEE Trans. Instrum. Meas.*, vol. 60, no. 12, pp. 3883–3891, 2011.

- [15] K. Liu, G. Motta, and J. Dong, “Wi-Fi-Aided Magnetic Field Positioning with Floor Estimation in Indoor Multi-Floor Navigation Services,” 2017 IEEE Int. Congr. Internet Things, pp. 129–136, 2017.
- [16] R. Faragher and R. Harle, “Location fingerprinting with bluetooth low energy beacons,” IEEE J. Sel. Areas Commun., vol. 33, no. 11, pp. 2418–2428, 2015.
- [17] A. Inc., “iBeacon for Developers,” 2014. [Online]. Available: <https://developer.apple.com/ibeacon/>.
- [18] A. Fujihara and T. Yanagizawa, “Proposing an Extended iBeacon System for Indoor Route Guidance,” Proc. - 2015 Int. Conf. Intell. Netw. Collab. Syst. IEEE INCoS 2015, pp. 31–37, 2015.
- [19] P. Dickinson, G. Cielniak, O. Szymanczyk, and M. Mannion, “Indoor positioning of shoppers using a network of Bluetooth Low Energy beacons,” 2016 Int. Conf. Indoor Position. Indoor Navig. IPIN 2016, no. October, pp. 4–7, 2016.
- [20] C. Fabritz, M. Abdelrahim, S. Wirsz, and T. Wang, “Open Specification for Indoor-Navigation,” Proc. - IEEE 11th Int. Conf. Semant. Comput. ICSC 2017, pp. 354–359, 2017.
- [21] H. M. Bluetooth and L. Version, “JNHuaMao Technology Company Bluetooth 4 . 0 BLE module Datasheet,” 2015.
- [22] Android and Google, “Android Studio Features | Android Studio,” Android, 2016. [Online]. Available: <https://developer.android.com/studio/features.html>.