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INDOOR POSITION ROUTING (IPR) AND DATA MONITOR USING BLUETOOTH LOW ENERGY TECHNOLOGY (iBEACON-BLE): AN IMPLEMENTATION STUDY

DÜŞÜK ENERJİLİ BLUETOOTH TEKNOLOJİSİ (iBEACON-BLE) KULLANARAK İÇ MEKAN KONUM YÖNLENDİRME VE VERİ MONİTÖRÜ: BİR UYGULAMA ÇALIŞMASI

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ABSTRACT

Rapid advancements in the mobile industry have emerged new technological ideas and applications for researchers by allowing smart devices over the last decade. In recent years, the need for Indoor Position Routing (IPR) and Location-Based Advertisements (LBA) systems are increasingly common, IPR and LBA systems have been becoming very popular. Nowadays, it has become possible to create software and hardware applications for IPR and LBA in indoor environments, thanks to developments of different technologies. The development of the system should be based on low-cost technology, it should be suitable for integration and indoor operation. New options and possibilities for indoor locations are presented by the iBeacon-Bluetooth Low Energy (BLE) radio protocol. iBeacon-BLE supports a portable battery-powered system that can be smoothly distributed at low cost giving it distinct advantages over Wi-Fi. Therefore, in this study, technological infrastructure is created to solve the navigation problem in closed locations using iBeacon-BLE technology, a data monitoring information system is proposed for smart devices of currently available technology for IPR, LBA with using iBeacon-BLE. The localization of the objects based on iBeacon-BLE and their combination are determined using the measured data with the developed application. To build an IPR system for indoor environments, the available hardware, software, and network technologies are presented. The concept of the indoor monitoring system and the technologies that can be used to develop the IPR system are presented. This system is made up of iBeacon-BLE sensor nodes, a smart device, and a mobile application that provides IPR and LBA services by measuring the distance between Transmitter (TX) and Receiver (RX). The proposed model uses the trilateration

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method, it allows the mobile application to determine the exact location of the object at the micro-level size. The proposed model uses sensory data to identify and trilateration the object's position.

Keywords: Bluetooth, BLE, iBeacon, Indoor, Mapping, Broadcasting, TX, RX.

ÖZET

Mobil endüstrideki hızlı gelişmeler, son on yılda akıllı cihazlara izin vererek araştırmacılar için yeni teknolojik fikirler ve uygulamalar ortaya çıkardı. Son yıllarda, iç Mekân Konum Yönlendirme (IPR) ve Konum Tabanlı Reklamlar (LBA) sistemlerine olan ihtiyaç giderek yaygınlaşmakta, IPR ve LBA sistemleri çok popüler hale gelmektedir. Son zamanlarda, farklı teknolojilerdeki gelişmeler sayesinde, iç ortamlarda IPR ve LBA için yazılım ve donanım uygulamaları oluşturmak mümkün hale geldi. Sistemin gelişimi düşük maliyetli teknolojiye dayalı olmalı, entegrasyona ve iç mekânda çalışmaya uygun olmalıdır. İç mekân konumları için yeni seçenekler ve olasılıklar, iBeacon-Bluetooth Düşük Enerji (BLE) radyo protokolü tarafından sunulmaktadır. iBeacon-BLE, taşınabilir pille çalışan sistemi destekler, Wi-Fi'ye göre belirgin avantajlar sağlayarak düşük maliyetle sorunsuz bir şekilde dağıtılabilir. Bu nedenle, bu çalışmada, iBeacon-BLE teknolojisi kullanılarak kapalı lokasyonlarda navigasyon problemini çözmek için teknolojik bir altyapı oluşturulmuş, iBeacon-BLE kullanılarak IPR ve LBA sistemleri geliştirilmiş, halihazırda mevcut teknolojiye sahip akıllı cihazlar için bir veri izleme bilgi sistemi önerilmiştir. Nesnelerin iBeacon-BLE'ye göre lokalizasyonu ve bunların kombinasyonu, geliştirilen uygulama ile ölçülen veriler kullanılarak belirlenmiştir. İç ortamlara uygun bir IPR sistemi oluşturmak için mevcut olan donanım, yazılım ve ağ teknolojileri sunulmaktadır. İç mekân izleme sistemi kavramı ve IPR sistemini geliştirmek için kullanılabilecek teknolojiler sunulmuştur. Bu sistem, iBeacon-BLE sensör düğümleri, bir mobil cihaz ve Verici (TX) ile Alıcı (RX) arasındaki mesafeyi ölçerek IPR ve LBA hizmetleri sağlayan bir mobil uygulamadan oluşur. Önerilen model trilaterasyon yöntemini kullanır, mobil uygulamanın mikro düzeyde, nesnenin tam konumunu bulmasına yardımcı olur. Önerilen model, bir nesnenin konumunu belirlemek ve trilaterasyon için sensörden gelen verileri kullanır.

Anahtar Kelimeler: Bluetooth, BLE, iBeacon, Konum, Navigasyon, TX, RX.

1. INTRODUCTION

IPR based on Bluetooth-BLE is not a new concept. (Munoz et al., 2012; Bruno & Delmastro, 2003). However, significant developments in iBeacon-BLE technology have increased the work in this area. In comparison to the previous models of Bluetooth, significantly lower consumption is a typical advancement of iBeacon-BLE. It has low development costs and is ideal for an extensive variety of mobile devices. iBeacon-BLE has great potential due to its advantages. It increases precision while reducing power usage and power costs. (Yamaguchi

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et al., 2015; Zou et al., 2016). Some types of mobile device-embedded sensors have significantly improved their ability to detect the indoor atmosphere and provide IPR opportunities.

Indoor location-based services provide some advantages for people to search places, products, or people. Possible areas of the indoor information system are for instance museums, airports, shopping centers, office buildings stations, and much more. Low energy consumption is the main benefit of BLE, allowing the transmitters known as Beacons to be constantly operated by batteries. It also makes it easier for the Beacons to be positioned where provide the electricity will be challenging. The proposed model has three parts a scan engine, distance calculation processor, and a graphical user interface. This study outlines the underlying concepts of indoor radio-based localization and focuses on the development of the android application. with the aim of new iBeacon-BLE technology.

This section has presented the motivation and goal of this study with the problem statement. The rest of the study is organized as follows: The literature review and related works are presented in section 2. The materials and methods used in this study are described in section 3. The development of the system with the used hardware and modeled architecture is presented in section 4. The experimental results with the discussions of the proposed system are given in section 5. Finally, the conclusions are remarked in section 6.

1.1. Problem Statement

Up to now, Outdoor Position Routing (OPR) is developed great success. However, the realization of IPR is facing completely some challenges such as distance measurement, the position determining, complying with suitable hardware and operating system, multipath effects and noise, radio environment, power efficiency, cost, lack of standardization, etc. OPR to determine the objects for outdoor has been resolved with GPS. It is mostly occurs based on GPS technique, it highly depends on the GPS signals. IPR requires a good accuracy in a range of a meter or even centimeters. For IPR, the accuracy of the position is not exact due to the weak signal of GPS. For this reason, there are various technologies for IPR in closed areas IPR to find the object with high accuracy. It is one of the IPR solutions in iBeacon-BLE. It is activated in order to detect location with BLE. Beacon devices regularly transmit Bluetooth signals consisting of letters and numbers to announce their presence to surrounding devices. Therefore, this study is focused on sensor-embedded mobile technologies to solve the IPR problem in large areas. Beacon-BLE devices have been used to provide accuracy, availability, and stability.

1.2. Motivation and Goal

With the developments of smartphones and usage in daily lives, navigating to the point to reach with high accuracy has become an obligatory part of not only daily work but also business life. Many user-friendly options such as having different road options to reach the point to go, being

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able to choose the shortest and least traffic routes, and offering suitable stopover points for needs on the route has made navigation an important part of life. For example, it can sometimes be quite difficult to reach the desired point in buildings with large, closed areas such as large shopping malls, airports, hospitals, congress halls, and factories. Therefore, in this study, an application has been made in the field of IPR which offers solutions to such problems. IPR is a technology that enables us to reach the point we want to reach in closed areas in the shortest way.

Location information can be obtained using a combination of Beacons, and navigation can be made to the desired point. Therefore, in this study, efforts are realized to make sense of distance and location data obtained from Beacons to provide useful guidance. The aim is to identify indoor locations through the use of iBeacon-BLE sensor nodes. For navigation assistance, this device utilizes particular location information obtained from iBeacon-BLE sensor nodes.
One of the goals of this study is to implement a data monitoring information system using iBeacon-BLE which is able to provide the IPR and LBA services. Smart devices in indoor areas can be benefited from the application to wander inside this area and reach desired places or services easily using the devices installed within the area thanks to IPR service. Besides, the LBB service can be sent location-related ads from specific places to smartphones in indoor areas. As mentioned in the literature review and related works, many studies have been completed based on iBeacon-BLE for indoor applications. One of the other objectives of this, the study is attempted to examine current models and implement a new system for the IPR and LBA. This study is aimed to build up an indoor information system for the android platform using the iBeacon-BLE.

2. LITERATURE REVIEW AND RELATED WORKS

Indoor positioning is a popular search field recently with many proposed technologies (Liu et al., 2007; Kaluza et al., 2017; Nuami & Kamel, 2011; Koyuncu & Yang, 2010; Mautz, 2009). A variety of survey papers on indoor localization are available in the literature and monitoring system with the discussing some kind of the latest indoor localization technologies and innovations in the area of monitoring user and user devices (Maghdid et al., 2016; Ferreira et al., 2017; Vasisht et al., 2016; Kotaru et al., 2015). Several systems were developed over the last decade based on Wi-Fi, optical, electromagnetic, Bluetooth, radiofrequency, and sound waves (Xiang et al., 2004; Kim et al., 2010; Saab & Nakad, 2011; Taskin, 2017). Many studies and developments are carried out dealing with BLE (Yu et al., 2012; Ali et al., 2011), and in the last few years, many low-energy Bluetooth systems have arisen. The BLE technology has potentially addressed indoor applications that are commonly used in large and medium-sized areas (Yang et al., 2015; Kjaergaard, 2010; Tesoriero, 2008). The distance between a mobile receiver and a point of reference was estimated (Zhou & Pollard, 2006). Two different positioning software was developed by using iBeacon-BLE and a smartphone (Yin et al., 2015). These studies show that the development process of indoor location services is continuing on

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the software and hardware side, no success has been achieved yet as in outdoor location services.

3. MATERIAL AND METHODS

In this section, the materials and methods used in the study are explained and the technical issues related to the development of the system are analyzed.

3.1. iBeacon- Bluetooth Low Energy (BLE) Technology

iBeacon-BLE is a Bluetooth-based concept that enables small and static pieces of data to be sent or retrieved by Bluetooth devices over short distances. It is sent the data to the application in a Universally Unique Identifier (UUID) form. BLE is described by its relatively limited dimension, low cost, low power consumption, and connectivity with handheld devices, tablets, and computers using a small power source. BLE technology is a less power-consuming type of conventional Bluetooth. It is a wireless connection technology and is extremely energy efficient. it is low power-cost, active just at the start of the beginning of communication, and then heading into sleep mode. iBeacon-BLE is shown in Figure 1. Also, the Signal zone of iBeacon-BLE is shown in Figure 2. It can track the smart devices if it enters or leaves a signal zone. The iBeacon-BLE technology highly supports indoor-mapping, marketing, malls, micro-location targeting, and a self-guided tour.

Figure 1: iBeacon-BLE device

Figure 2: Signal zones of the iBeacon-BLE device

The working model of the proposed system is illustrated in Figure 3. The working model of the proposed system consists of the following steps: Beacons periodically send a signal that all BLE supporting devices can receive. These signals contain various Bluetooth metadata including the device identification information (ID) and the quality of the transmitted signal. The devices in receiver status receive and analyze the message sent by the Beacons. The smart devices calculate the approximate distance from the Beacons according to the RSSI information inside the message. The smart devices learn which object/product/aisle is approaching according to identity information. In the positioning solution presented in this study, the location is determined according to the proximity information obtained from the quality of the signals.

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Because, in this system, the location determination is determined by the proximity to the Beacon devices that are placed in a fixed place indoors and whose location information has been previously defined. Applications take action according to this proximity information obtained by calculation.

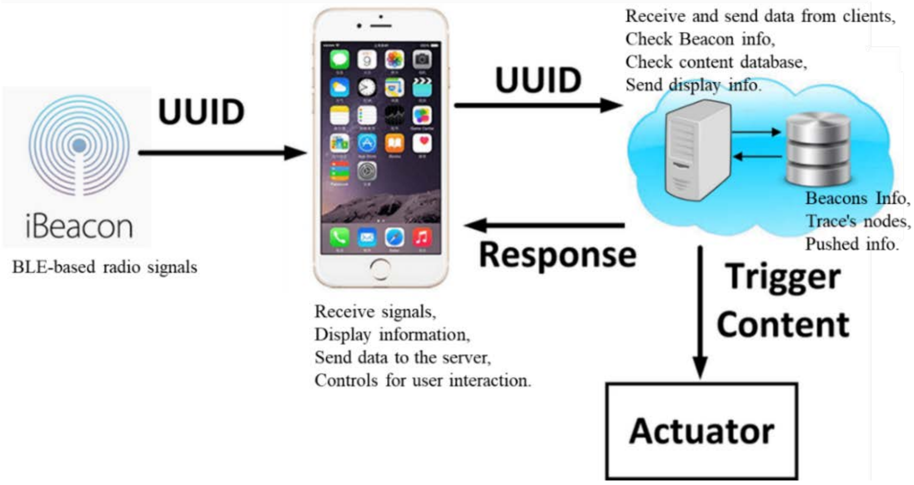

Figure 3: The architecture of iBeacon-BLE technology

The BLE protocol is especially important for the Internet of Things (IOT) which is used when there is no need for large amounts of data exchange. The BLE protocol is among the technologies that find a place in many devices today. The proposed model is planned as an architectural multi-layer. The Beacon plays a significant role in the hardware layer. Each Beacon is equipped with separate transmitting power and physical location in this model. Figure 4 shows the BLE protocol stack architecture. As shown in Figure 4, this protocol stack of the BLE technology consists of two sections.

Table 1: Comparison of well-known indoor positioning techniques

	Wi-Fi	RFID	Beacon-BLE
Coverage	50m	10m	50m
Cost	High	Low	Low
Power Consumption	High	Low	Low
Bandwidth	1.8G	250kb	1M
Battery Life	1-2 years	1-2 years	5-6 years
Positioning Accuracy	2m-3m	1m-2m	10cm-20cm
Operating System	IOS, Android	IOS, Android	IOS, Android

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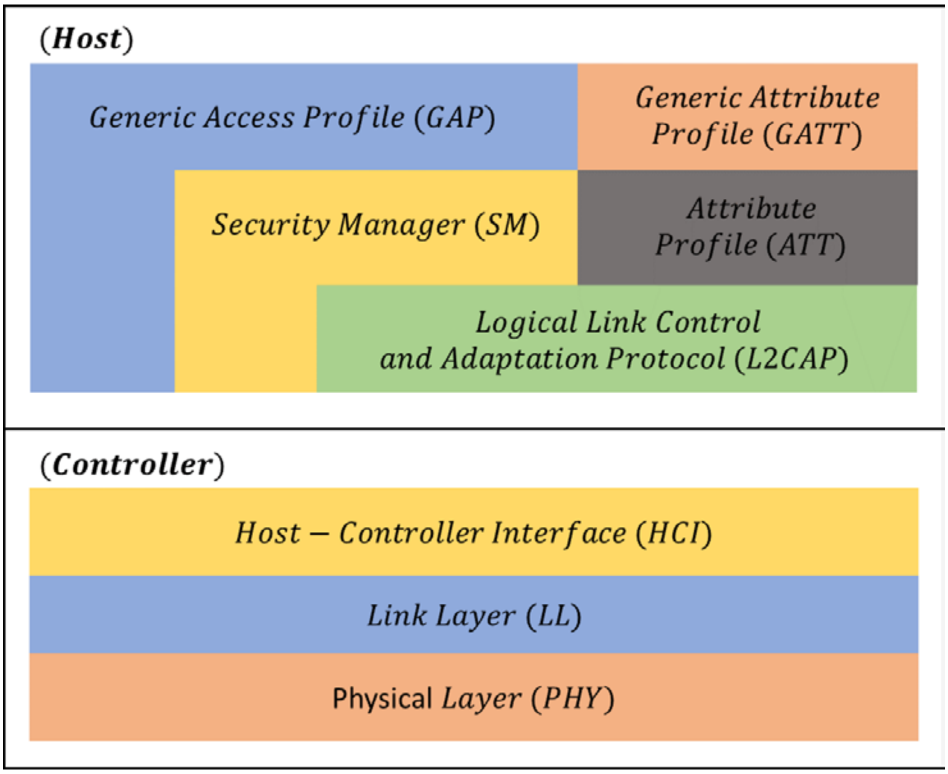

Figure 4: The architecture of the BLE protocol stack

The controller part is responsible for handling physical hardware signals. It manages the timing of incoming and outgoing packets and monitoring the flow of data at the physical level. The host part is responsible for the L2CAP feature, attribute protocol, application, and security manager. L2CAP provides a channel platform for communication between data services, it encapsulates data for the upper service layers. GAP is responsible for managing device discovery and link-related resources to the application layer, such as ads, scanning, etc. SM offers an encryption engine for authentication, pairing, and delivery of keys. ATT is responsible for deciding the device's function like master/slave or server/client. GATT is a service framework, and It communicates with the configuration profiles of the application layer. The differences between well-known IPR techniques are presented in Table 1. Technical Specification of the iBeacon-BLE technology is given in Table 2. It is presented that from Table 1 and Table 2, the benefits of iBeacon-BLE are low cost, large coverage, perfect accurate positioning, low energy consumption.

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Table 2: Technical Specification of the iBeacon-BLE technology

Distance/Range (theoretical max.)	50 m (160 ft)
Over the air data rate	1 Mbit/s
Application throughput	0.27 Mbit/s
Active slaves	implementation-dependent
Security	128-bit AES with Counter Mode CBC-MAC
Robustness	24-bit CRC, 32-bit Message Integrity Check
Latency (from a non-connected state)	6 ms
Total time to send data (det.battery life)	3 ms, <3 ms
Network topology	Scatternet
Power consumption	0.01o 0.05 (depending on use case)

3.2. Received Signal Strength Indicator (RSSI) and Decibel-milliwatts (dBmW)

The Received Signal Strength Indicator (RSSI) is one of the simplest and widely used techniques used to measure the distance (Krishnan et al., 2013; Ladd et al., 2005). It is a measure of how far a signal from an access point can be heard from smart devices. The RSSI has no absolute value, but it is a value used to determine whether sufficient signal has been obtained to obtain a good wireless connection. The standard IEEE 802.11 specifies that RSSI should be on a scale from 0 to 255 and that each manufacturer of a chipset can determine its RSSI value. It can be concluded that the magnitude of the RSSI is the better signal. The closer to 255 RSSI is the better signal.

The Decibel-milliwatts (dBmW) and the RSSI are different units of measure, both representing the signal strength. The distinction is that while dBmW is an absolute number reflecting power levels in mW, the RSSI is a relative index. Generally, the distance between the receiver of a radio frequency signal and the source of that signal can be computed. Radiofrequency signal strength measures are expressed in dBm. The received signal strength is measured on a dBm scale. The closer to 0 dBm is the better signal. The relationship between the received signal strength (RSSI, in dBm) and distance (in meter) was expressed in Equations (1), (2), and (3).

3.3. Indoor Radio Propagation Model

Multiple localization protocols use RSSI for the location of a radio system. Several types of research about signal transmission were carried out over the years and some experimental formulas were proposed (Chai et al., 2016; Salas, 2014; Estel & Fischer, 2015; Balakrishnan, 2017). Linear Curve Fitting (LCF) is a widely used and well-known model, it is expressed in Eq. (1).

$$RSSI(d) = [RSSI(d_0) - 10 * n * \log(\frac{d}{d_0})] \quad (1)$$

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where: d parameter is the received signal strength at distance between the TX and RX, d_0 a parameter is the received signal strength at a distance of $1m$ of the device, $RSSI$ is the signal from the Beacons, n parameter is the signal propagation constant or path-loss exponent which depends on the propagation environment.

Using $d_0 = 1m$ and solving equation (1) for d the Equation (1) is simplified to Eq. (2).

$$d = 10[\frac{RSSI_{d_0} - RSSI(d)}{10*n}] \quad (2)$$

n parameter depends on the transmission medium, the TX, the RX, and the value of d. The distance calculation method is proposed based on calculating the path loss index using only RSSI values. So, the path loss exponent can be expressed in Eq. (3).

$$n = [\frac{RSSI_{d_0} - RSSI(d)}{10*\log(\frac{d}{d_0})}] \quad (3)$$

3.4. Trilateration Positioning Technique

There is some kind of techniques for indoor positioning systems such as trilateration, triangulation, fingerprinting, etc. Trilateration is a conventional technique that uses the 2D geometry of circles to calculate the position of points by determining distances from three reference points. So, at least 3 Beacons should be used for position detection with the trilateration technique. The Beacons have a specific range which is represented as a circle with a radius of the distance. The junction of the three circles is the current position. The location can be determined by measurement of distances and the current location can be calculated by RSSI. The RSS is the signal power strength and measured in dBm or mW to estimate the distance between a TX and RX. Thus, the trilateration algorithm is used as a positioning technique in this study. This is based on RSSI calculated distances and promised high accuracy. The algorithm codding is simple and requires low infrastructure. The first step is calculating the distance to the Beacon based on RSSI with LCF. The second step is determining the position using the trilateration algorithm. The diagram of the Trilateration-based localization is illustrated in Figure 5. The absolute distance between the smart device and a minimum of three points of reference is calculated using the RSSI in the devices. To achieve its location relative to reference points, geometry is applied to the smart device as seen in Figure 5.

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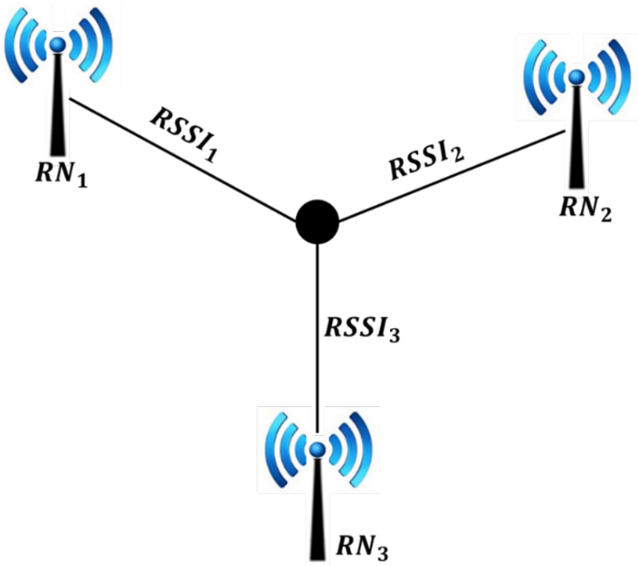

Figure 5: Diagram of the trilateration-based localization

3.5. Functional Definitions of the System

Functional definitions should be determined before the application development phase and the necessary definitions should be made according to these criteria. Functional definitions in this study consist of zone monitoring, the transition between devices, retrieving data, updates, authority-based requirements. The BLE signals are listened to by the application in the background, when it detects some device, it should generate a notification to the smart device of the user for zone monitoring.

The Transition between devices is calculated as approximate. The distance between the transmitting device and receiving device is categorized into 3 different ranges. As seen in Figure 2, the ranges are Immediately, Near, and Far. Immediately range is a few centimeters, the near range is a few meters, the far range is over 10 meters. The maximum range of a Device transmission is depending on its location, place, placement, and environmental obstructions. The BLE device transmits a strict format, a prefix, followed by a variable UUID, major and minor IDs for retrieving data. The publisher side only sends data. The standard device stream consists of a UUID, only one Major, and one Minor value.

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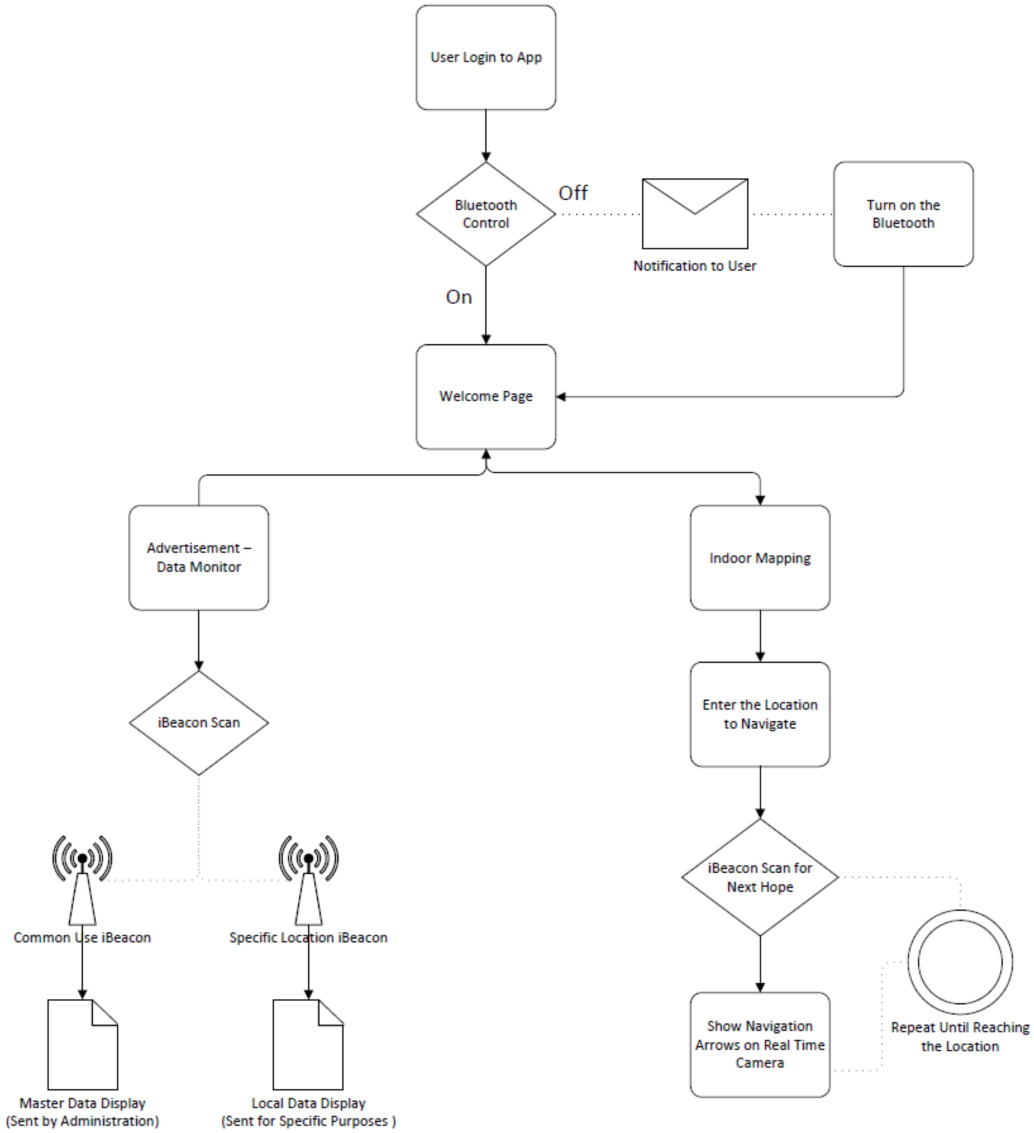

Figure 6: Working flow diagram of the developed application

The favorite places of the user are determined in the regions, it is determined whether the user's Bluetooth is turned on, users should be able to receive ad notifications instantly, users should have filtering and search capabilities. Application administrators should have managed tasks from the interface such as load ads, control free time periods, view statistics, schedule ads, request promotional notifications, configure on the devices. Administrators must have control of the advertising content send to users, have control of their implementation plans, and have access to reports. Besides, administrators must be able to personalize ads based on specific users' shopping preferences and have access to all device information.

There are two types of updates, application update, and device update. If there is a new version of the application, the application should check the server. Besides, devices always broadcast data to smart devices, this data should always be kept up to date.

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4. DEVELOPMENT OF THE SYSTEM

In this section, the steps of the development of the system to transform the study into practice are explained such as used devices, system structure, and developed programming codes. The development of the system from the application side and the used techniques are presented. The methods used in application development are illustrated with examples. The working flow diagram of the developed application is presented in Figure 6.

4.1. Technical Structure of the System

The system is based on iBeacon-BLE devices that broadcast 3 IDs continuously with the BLE protocol and the main structure that listens to these devices and returns data from the database in return. Beacon devices are powered by a small battery and can be used in a very modular way as they can remain active for years with these batteries. It is broadcasted with 3 IDs: a unique ID number, major and minor ID, which are assigned to each iBeacon-BLE device. Although all these data are meaningless, all requested information sharing, and directions are made by the algorithms on the software side.

4.2. Scanning BLE Signal

The listening signal coming from BLE devices is shown in Figure 7. It is for smartphones that take the signal from BLE devices and shows notification according to signal that comes via BLE. Application is started to listen to BLE signals and scanning them according to set time period. It scans the signal every 5 seconds. So, it can understand it takes the signal from another device.

4.3. Distance Measurement with the iBeacon-BLE Signals

The developed system can understand the distance of the signal center. It can provide current distance information to each device. According to the signal strength, the application can show the information of the BLE device. Distance analysis of Beacon devices in the environment is shown in Figure 12 (a). In order to decide how close a Beacon is, TX power is used. All devices have a TX Power value, it describes the RSSI value in 1m distance and provides information about the signal strength received by the application (Kriz et al., 2016). To measure the distance from a mobile to a Beacon, LCF needs to be implemented in the application. The android Beacon library can be used to measure the distance (Cho et al., 2015). Accordingly, a comparison is made about the distance. Figure 8 shows the process of calculating distance and signal strength comparison.

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```
public void scanBLE devices(final boolean enable) {
    if (enable) {
      // Stops scanning after a pre-defined scan period.
      _timeoutHandler = new Handler();
      _timeoutHandler.postDelayed(timeoutTask, BLE deviceProtocol.SCANNING_PERIOD);
        _scanning = true;
      _arrOrderedBLE devices.clear();
      _bluetoothAdapter.startLeScan(mLeScanCallback);
      _listener.searchState(SEARCH_STARTED);
    } else {
      _scanning = false;
      _bluetoothAdapter.stopLeScan(mLeScanCallback);
      _listener.searchState(SEARCH_END_SUCCESS);   }
        // Cannot obtain error status=133 this way
    Log.i(Utils.LOG_TAG,"The status:" + _bluetoothAdapter.getProfileConnectionState(BluetoothProfile.GATT));  }
    // Direct call to start scanning for BLE devices
  public void startScan(){
    if(_bluetoothAdapter != null)
      scanBLE devices(true);  }
```

Figure 7: Listening signals coming from BLE devices.

```
private double calculateDistance(int txPower, double rssi) {
    if (rssi == 0) {
      return -1.0; // if we cannot determine accuracy, return -1.   }
    double ratio = rssi*1.0/txPower;
    if (ratio < 1.0) {
      return Math.pow(ratio,10);  }
    else {
      double accuracy =  (0.89976)*Math.pow(ratio,7.7095) + 0.111;
      return accuracy;  } }
  // Implements a proximity comparator of distance for BLE devices
  private class BLE deviceProximityComparator implements Comparator<BLE device> {
    @Override
    public int compare(BLE device b1, BLE device b2) {
      return b1.getProximity()-b2.getProximity();  } }
```

Figure 8: Calculating distance and signal strength comparison

4.4. Beacon-BLE ID Numbers and Settings

UUID is the standard identification system that allows the creation of a unique number for a device. Major and Minor ID values are numbers assigned to the device for more accurate identification than using a UUID alone. Major and Minor ID values are unsigned integer values between 0 and 65535. The BLE device standard requires the assignment of both Major and Minor ID values. UUID stands for Universal Unique ID. Each of the 5 groups must contain the following number of characters per section. It is contained 32 hex digits separated by dashes, divided into 5 groups, and it should be looked like in below:

f7826da6-4fa2-4e98-8024-bc5b71e0893e

First part: 8, second part: 4, third part: 4, fourth part: 4, fifth part: 12.

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```
public static final byte[] UUID = {(byte) 0xA7, (byte) 0xAE, (byte) 0x2E, (byte)
0xB7, (byte) 0x1F, (byte) 0x00, (byte) 0x41, (byte) 0x68, (byte) 0xB9, (byte) 0x9B,
 (byte) 0xA7, (byte) 0x49, (byte) 0xBA, (byte) 0xC1, (byte) 0xCA, (byte) 0x64};
   // Configure the UUID, major a minor of sample BLE devices
   private BLE device _sampleBLE device1 = new BLE device(UUID, 1, 1);
   private BLE device _sampleBLE device2 = new BLE device(UUID, 1, 2);
   private BLE device _sampleBLE device3 = new BLE device(UUID, 1, 3);
   private Handler mHandler;
```

Figure 9: Assigning ID numbers to devices on Bluetooth via application

As seen in Figure 9, the UUID must be defined as hex digits, the Major and Minor IDs can be defined as an integer. After these adjustments are over, the devices will start broadcasting these 3 IDs with Bluetooth packages without interruption. section 5.

```
public boolean isSameRegionAs(BLE device BLE device) {
      if (BLE device == null) {
         return false;   }
      if(getUuidHexString().equals(BLE device.getUuidHexString())
            && _major == BLE device.getMinor()
            && _minor == BLE device.getMinor())
         return true;
      return false;   }
   @Override
   public String toString() {
   return "UUID:" + this.getUuidHexString() + " M:" + this.getMajor() + " m:" + this.getMinor() + " p:" + this.getProximity();
```


Figure 10: Major and Minor IDs listening via application

4.5. Bluetooth Packet Listening by Application and reading ID

The software has 3 IDs to listen to, and these IDs must be defined to the application. Thus, the application listens and lists all Beacon devices that are in the environment and receive signals. In this case, the content of each ID must be defined separately in the application. The listening process of IDs (Major, Minor, and UUID) via application is given in Figure 10 and Figure 11. Monitoring iBeacon-BLE devices in the environment is shown in Figure 12 (a). As seen in Figure 12 (a), IDs are read-only once, and the same information is shown continuously. After the definitions made here, a mobile GUI is used to view the devices in the environment. All details of the devices are displayed on this interface. Mobile GUI for scanning signals at power-on is shown in Figure 12 (b). In case of entering a new device into the area, the data here remains constant. To solve this, it is needed to loop this scanning process with a counter and repeat it. The process of providing continuous scanning by adjusting the counter is shown in Figure 13.

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```
public byte[] getUuid() {
    return _uuid;  }
  public String getUuidHexString(){
    String s = "";
    for(int i=0;i<_uuid.length;i++)
      s += String.format("%02X", _uuid[i]);
    return s;   }
  public String getUuidHexStringDashed(){
    String uuid = getUuidHexString();
    String newUuid = uuid.substring(0,8) + "-" +
        uuid.substring(8, 12) + "-" +
        uuid.substring(12, 16) + "-" +
        uuid.substring(16, 20) + "-" + uuid.substring(20);
    return newUuid;  }
```

Figure 11: Listening UUID via application

Figure 12: (a) Monitoring and distance analysis of Beacon devices in the environment, (b) GUI for Scanning Signals at Power On, (c) Displaying the data corresponding to the closest Beacon.

4.6. Sending the Received ID Numbers to the Database

After the IDs are received in the iBeacon-BLE device, these IDs must be sent to the database in order to perform a functional operation, the application must return according to the corresponding data or function. In this case, the most efficient method used to send 3 IDs to the database is the JSON object file. It is a data exchange format based on the Key-Value relationship. In other words, it is the data type in which data can be associated and stored with key data. By assigning various references (Key) to the data in the database, only the data needed is accessed. In this study, 3 IDs are encapsulated with JSON objects and transferred to the database. In this way, the security of the system has been increased. The process of encapsulating IDs with JSON objects and transferred them to the database is shown in Figure 14. After the ID data in the package is sent as a JSON object, the Volley library is used to send them to the database. The definitions in this library ensure that JSON object packages are put

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in a queue and transmitted to the database. Putting JSON Object files in the queue and transmitting them to the database is shown in Figure 15.

```
TimerTask searchBLE deviceTask = new TimerTask() {
        @Override
        public void run() {
            runOnUiThread(new Runnable() {
                @Override
                public void run() {
                    scanBLE devices();  }  });  }  };
    Timer timer = new Timer();
    timer.scheduleAtFixedRate(searchBLE deviceTask, 1000, 2 * 10 * 500);
```

Figure 13: Providing continuous scanning by adjusting the counter on the application

```
JSONObject BLE deviceServer = new JSONObject();
    try {
        BLE deviceServer.put("uuid", UU_ID);
        BLE deviceServer.put("major", MAJOR_ID);
        BLE deviceServer.put("minor", MINOR_ID);
    } catch (JSONException e) {
        e.printStackTrace();   }
```

Figure 14: Encapsulating IDs with JSON object and transferred to the database

4.7. Reading the Data from Database by the Application

After sending the IDs distributed by iBeacon-BLE devices to the database, the data corresponding to these ID numbers and the desired functions in the database should be read by the application. The POST method was used to send ID numbers to the database. The GET method is used to read the data in the database by the application. Volley library makes a JSON request, a call to the URL is made and the parsing process is done, finally, the parsed response is added to a string and displayed on the screen. The volley automatically caches requests and prevents significant waste of resources. An example of a JSON object file read from the database is shown in Figure 16. Also, the process of reading data corresponding to IDs by the application is shown in Figure 17.

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```
request = new JsonObjectRequest(Request.Method.POST, URL, BLE deviceServer,
        new Response.Listener<JSONObject>() {
          @Override
          public void onResponse(JSONObject response) {
            Log.e("response", response.toString());   }
        }, new Response.ErrorListener() {
      @Override
      public void onErrorResponse(VolleyError error) {
        Log.e("Error Response", error.toString());   }  });
    queue.add(request);
      mTextViev1 = (TextView) findViewById(R.id.mTextView);
     RequestQueue queue2 = Volley.newRequestQueue(this);
     JsonObjectRequest jsonObjRequest = new JsonObjectRequest
        (Request.Method.GET, URL, BLE deviceServer, new Response.Listener<JSONObject>() {
          @Override
          public void onResponse(JSONObject response) {
            Log.e("success",response.toString());
            mTextViev1.setText("Response: " + response.toString());  }
        }, new Response.ErrorListener() {
          @Override
          public void onErrorResponse(VolleyError error)  });
    queue2.add(jsonObjRequest);   }
```

Figure 15: Putting JSON Object files in the queue and transmitting to the database

```
{  "name" : "Rosa Brill",
  "email" : "rasabrill@gmail.com",
  "phone" : {
    "home" : "08947 000000",
    "mobile" : "9999999999"     }  }
```

Figure 16: A JSON object file read from the database

4.8. Creating Singleton Pattern in the Application

If the application makes constant use of the network, it is probably most efficient to set up a single instance of request queue that will last the lifetime of the application. In this study, the applied approach is to implement a singleton class that encapsulates request queue and other volley functionality. The queue of the request should be instantiated with the context of the application instead of the activity context. This process ensures that the request queue will last for the lifetime of the application instead of being recreated every time the activity is recreated. An example of performing request queue operations using the singleton class is shown in Figure 18.

4.9. Display Data on the GUI and Signal Analysis

After all database connections, the answers received from the database are displayed in the mobile application. Therefore, an interface and dynamic page are designed for applications. It is ensured that the user sees every notification from the nearest BLE device. The app always scans BLE devices in the background and calculates which device is closest, then sends the IDs of the closest device to the database and fetches notifications about it. On the application screen, location-based data, advertising, etc., is displayed.

In the testing phase of this study, 3 devices were used, and these devices were defined as 1,2, and 3 devices in the software. These devices have constantly scanned and the data of the device with the highest signal strength has displayed on the screen. Sample data to be displayed on the screen for 3 devices is shown in Figure 20.

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```
 //Method to make json object request where json response starts  {
private void makeJsonObjectRequest() {
   showpDialog();
   JsonObjectRequest jsonObjReq = new JsonObjectRequest(Method.GET,
         urlJsonObj, null, new Response.Listener<JSONObject>() {
            @Override
            public void onResponse(JSONObject response) {
               Log.d(TAG, response.toString());
               try {
                  // Parsing json object response , response will be a json object
                  String name = response.getString("name");
                  String email = response.getString("email");
                  JSONObject phone = response.getJSONObject("phone");
                  String home = phone.getString("home");
                  String mobile = phone.getString("mobile");
                    jsonResponse = "";
                  jsonResponse += "Name: " + name + "\n\n";
                  jsonResponse += "Email: " + email + "\n\n";
                  jsonResponse += "Home: " + home + "\n\n";
                  jsonResponse += "Mobile: " + mobile + "\n\n";
                    txtResponse.setText(jsonResponse);
                 } catch (JSONException e) {
                  e.printStackTrace();
                  Toast.makeText(getApplicationContext(),
                        "Error: " + e.getMessage(),
                        Toast.LENGTH_LONG).show();   }
                             hidepDialog();   }
         }, new Response.ErrorListener() { |
            @Override
            public void onErrorResponse(VolleyError error) {
               VolleyLog.d(TAG, "Error: " + error.getMessage());
               Toast.makeText(getApplicationContext(),
                     error.getMessage(), Toast.LENGTH_SHORT).show();
               // hide the progress dialog
               hidepDialog();  }  });
   // Adding request to request queue
   AppController.getInstance().addToRequestQueue(jsonObjReq);  }
```

Figure 17: Reading of data corresponding to IDs by the application

After the in-app visual designs are made, the scanning is started, and the closest device data is expected to be displayed on the screen. GUI for Scanning Signals at Power On is shown in Figure 12 (b). Since the signal from the number 1 Beacon is stronger after scanning, the data monitor is shown in Figure 12 (c) was made. Displaying the data corresponding to the closest Beacon is shown in Figure 12 (c). In addition to viewing data, a drawing with the locations of the Beacon devices should be determined in order to perform indoor mapping, the distance of the user to the devices and the walking movements according to the data received from the gyroscope should be analyzed with a software algorithm and should be directed to the desired location. In Figure 19, a sketch of Beacon devices, the path and gyroscope data are taken according to the signals are shown graphically.

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```
public class MySingleton {
  private static MySingleton mInstance;
  private RequestQueue mRequestQueue;
  private ImageLoader mImageLoader;
  private static Context mCtx;
  private MySingleton(Context context) {
    mCtx = context;
    mRequestQueue = getRequestQueue();
    mImageLoader = new ImageLoader(mRequestQueue,
        new ImageLoader.ImageCache() {
      private final LruCache<String, Bitmap>
          cache = new LruCache<String, Bitmap>(20);
      @Override
      public Bitmap getBitmap(String url) {
        return cache.get(url);  }
      @Override
      public void putBitmap(String url, Bitmap bitmap) {
        cache.put(url, bitmap);  }      });     }
  public static synchronized MySingleton getInstance(Context context) {
    if (mInstance == null) {
      mInstance = new MySingleton(context);        }
    return mInstance;     }
  public RequestQueue getRequestQueue() {
    if (mRequestQueue == null) {
      // getApplicationContext() is key, it keeps you from leaking the
      // Activity or BroadcastReceiver if someone passes one in.
      mRequestQueue = Volley.newRequestQueue(mCtx.getApplicationContext());   }
    return mRequestQueue;  }
  public <T> void addToRequestQueue(Request<T> req) {
    getRequestQueue().add(req);  }
  public ImageLoader getImageLoader() {
    return mImageLoader;  } }
```

Figure 18: An example of performing request queue operations using the singleton class.

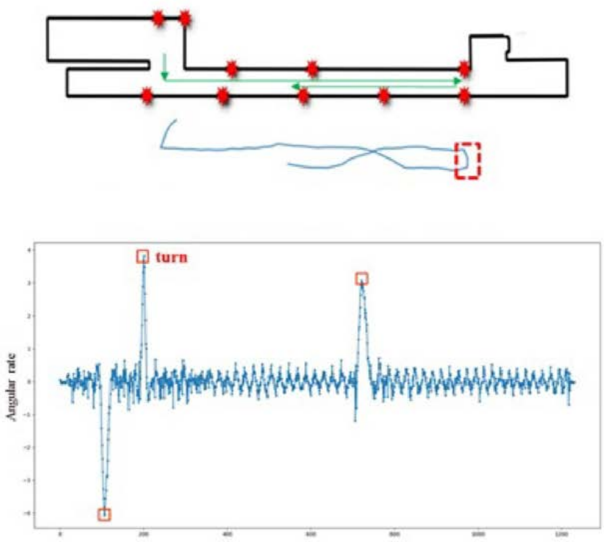

Figure 19: Indoor Signal Analysis

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```
public static Offer getSampleOffer1(){
        Offer o = new Offer();
        o._offerId = 1;
        o._description = "New Engineers";
        o._discountTextBig = "Fresh Brains";
        o._discountTextSmall = "Fresh Ideas";
        o._discountInfo = "Future's Technology";
        o._imageId = R.drawable.offer1;
        return o;  }
    public static Offer getSampleOffer2(){
        Offer o = new Offer();
        o._offerId = 1;
        o._description = "Education";
        o._discountTextBig = "Learn ";
        o._discountTextSmall = "to Live";
        o._discountInfo = "Best way to learn";
        o._imageId = R.drawable.offer2;
        return o;   }
    public static Offer getSampleOffer3(){
        Offer o = new Offer();
        o._offerId = 1;
        o._description = "Ugarit Tech";
        o._discountTextBig = "You Think";
        o._discountTextSmall = "We do";
        o._discountInfo = "Creating Tomorrow";
        o._imageId = R.drawable.offer3;
        return o;  }
```

Figure 20: Sample data to be displayed on the screen for 3 devices

5. RESULTS AND DISCUSSIONS

As a result of the tests performed in different environments, it has been observed that the location determination made in the open environment gives better results than indoor environments. However, the distance at which the signals are received strongly in both environments is 2.5 to 3 meters away. When the distance of the object whose location was tried to be determined exceeded 3 meters from the phone, a serious decrease was observed in the received signals. A distance of 3 meters is a short distance for locating, considering the situation that today's technology has come to. For this reason, it is necessary to develop both iBeacon-BLE devices and Bluetooth sensors of mobile devices to find the location more accurately.

In case the necessary improvements are made, the application developed can be useful and effective in locating the objects. Thus, it will both facilitate people's lives and save time. According to the data obtained from the demo application, it is proved that iBeacon-BLE is a very efficient technology with the correct application and correct developments, it has been seen that it can be integrated into many areas. Other discussion issues such as device security, signal jammers, switching between devices, loss of connection, zone detection, additional functions, user benefits, device registration to the map are set out below.

5.1. Device Security

Device packages are sent to the application with BLE technology. Therefore, user information should be saved and not be attacked by anyone else. It is the same for both devices and applications. The device must be so secure that no one else can add or delete data, and the app

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must be so secure that no one else has a chance to see the data. The device UUID, major and minor IDs can be changed, so it is necessary to make it secure enough to block others.

5.2. Interferences and Signal Disrupts

Since it is not a CleanAir environment, interference is the main challenge in device technology, and Microwave Ovens, DECT phones, etc. it is low energy that can easily be canceled by stronger interference. These difficulties are very common and have unexpected consequences. RSSI signals have been used to determine the estimated location of smart devices. The system is usable by unlimited mobile phone users simultaneously.

5.3. Cross-Device and Zone Detection

The developed application can detect a device, find a second device, and then switch between the two of these devices can cause problems. When near a device, it can move between different distances, thinking it is far away. Errors in distance calculation can cause problems. Therefore, control algorithms should be developed and embedded in the software for inter-device transition and distance calculations.

5.4. Short Term Connection Lost and Lock Screen Notifications

The application may lose all communication with the devices for a very short time. The coding strategy that will minimize the connection losses should be investigated. Some phones may receive delayed notifications when the screen is locked. There may be delays in receiving lock screen notifications and may cause some false notifications. For this reason, tests should be performed on different brand model devices, the response and sensitivity of the application against different chipset developers should be measured.

5.5. Background Mode and Bluetooth Activation

The application may behave differently in different foreground modes while in background mode, or it may not detect devices at all if the user forcibly closed the app. The solution to these situations requires in-depth research and long-term tests. There may be many devices with Bluetooth turned off. To connect a device, you need devices with Bluetooth turned on, this is one of its main challenges. Sometimes users turn off the Bluetooth device. If some information such as where the device is located can be recorded on the map, when the user enters the location, a message can be sent with GPS to enable the Bluetooth device. This is one possible way to fix the problem.

5.6. User Benefits

After using the application for a while, the application will provide more information about the users. It can be ensured that some ads that users are most interested in are shown more. A list of the most visited places and favorite places can be made. Besides, data about how long a user stayed in that place can be kept.

6. CONCLUSIONS

in this study, technological infrastructure is created to solve the navigation problem in closed locations using iBeacon-BLE technology, a data monitoring information system is proposed for smart devices of currently available technology for IPR, LBA with using iBeacon-BLE. An

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indoor information monitoring system is proposed that consists of BLE advertising nodes and a smart device application. The system is developed with the proposed model to locate the position of an object or person in an indoor application. The proposed model has presented the combination of iBeacon-BLE and the application for Android is effective and satisfactory. Using the data calculated with the built program, the localization of items dependent on iBeacon-BLE and their combination is assessed. The available hardware, software, and network technologies are presented for creating a positioning system for an indoor area. The concept of the indoor monitoring system and the technologies to develop the IPR system are presented. This system consists of iBeacon-BLE sensor nodes, a smart device, and an application that provides IPR and LBA services by measuring the distance between TX and Receiver RX. The proposed model uses the trilateration method, this ensures the mobile app to identify the precise location of the object at a micro-level scale. The proposed model uses sensory data to recognize and trilateration the position of an object. With the tests carried out, it has been observed how effective the iBeacon-BLE devices are in determining the location, and it has been shown that the Beacon technology must be developed more to make the location detection more accurate.

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