An iBeacon-Based Location-Aware Advertising System

by

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The billboard market near its end for the development of electric commerce, especially with the maturing of online advertising systems. Traditional billboards demand innovative ways to attract and categorize users; and to direct them to desired advertisements. Location information is the prerequisite to pinpoint the users or customers. Location information collection, GPS and cellular networks are better for outdoor navigation than indoor positioning. The emergence of Bluetooth Low Energy technology provides an efficient approach for indoor positioning services. In this thesis, we propose an iBeacon based location aware advertising system to make users acquire the desired advertisement. The system includes the server side, user side and billboard side. We will go into details about its concept, implementation and related background in the thesis. Finally, we analyzed the performance of the system and showed that the system is suitable for indoor environments.

Acknowledgements

I would like to thank my professor Pin-Han Ho for all his help and encouragement in my studies of the MASc program and this work. I would like to acknowledge the contributions of Cyphy for providing DragBeacon and related SDK to the App development.

Dedication

This thesis is dedicated to my beloved parents and friends.

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Chapter 1

Introduction

Along with the expansion of electronic commerce, the online advertising system have developed greatly. However, the advertising system in the real world market mainly adopts the billboard to display the advertisements and lacks the interaction with customers. With the increase in users of Smart Mobile Media Device(SMMD), the Smart Mobile Media Service(SMMS) and machine-to-machine(M2M) devices are gaining momentum in the market today[4]. The traditional advertising strategy is moving from the billboard to intelligent mobile. The Mobile advertising has the following appealing features[3]:

- Portability: The mobile device is portable and fits in a pocket.
- Personalization and Instant Access: The mobile application will give different responses according to the identity of users and is able to receive the instant access from users most of the time.
- Mobility and Wireless Internet Connectivity: The mobile device need wireless links to connect to the Internet.
- Location-aware: The mobile device is able to provide location information to enable the specific functions.
- Context-aware: The mobile application will recognize the environment given by users.

All of the above make the mobile a suitable device for LBS(Location Based Service). The LBS is a service that is triggered by the specific location information. There are three business models for LBS mobile advertising[3]:

- Network service provider-dependent business scenarios: The network service provider allows the devices and infrastructure to give the users location based service. In this model, the network service provider garners the most revenue.
- Network service provider-assisted business scenario: The network service provider just provides the network service to assist the user to download or upload data. The location data or information are provided by the independent LBS provider. The LBS provider may provide free services.
- Network service provider-independent business scenario: The LBS provider may not use the network service provided by the network service provider. They work independently and the user can choose the services according to their preference.

The options of business models are flexible, which makes LBS mobile advertising adaptable to various business environment. The second business model is a good choice because the wifi is widespread and it is difficult for vendor or non-technical organization to construct the network service. In this thesis we will present an iBeacon based location-aware advertising system. The network service plays an assistant role for user to download the advertisements according to the signal distributed by the independent iBeacon provider.

1.1 Motivation

Although the web services are full of various online advertising system, the billboard is still a pervasive advertising method in real world markets. We can imagine a scenario: when customers enter into an shopping mall, they use the map or billboard to search the stores or vendors. It is inconvenient for customers to search for a specific location especially considering the navigation services provided by mobile. Hence, a new advertising method which incorporates with the navigation service attracts our attention. The new method is the location based service advertising system. The LBS advertising system has different implementation and in our implementation we adopt iBeacon as the LBS provider to construct the advertising system.

1.2 Thesis Contributions

This thesis is presenting an iBeacon-based location-aware system that makes users interact with billboards at specific locations. The system consists of:

- The Bluetooth Low Energy(BLE) devices: In this system, the iBeacon is utilized as the BLE device to broadcast the Bluetooth signal. The signal covers a small area. The mobile device which enters into the region will receive the signal and make the corresponding response.
- The cloud servers provide download service and the local servers arrange the display sequence of the advertisements.
- The mobile application as user terminal: The mobile application will detect the hand movement of users and recognize the broadcast signals of iBeacon to download the specific advertisements.

Figure 1.1 is the illustration of the system. In the following chapters, we will introduce the related background and the implementation of this system.

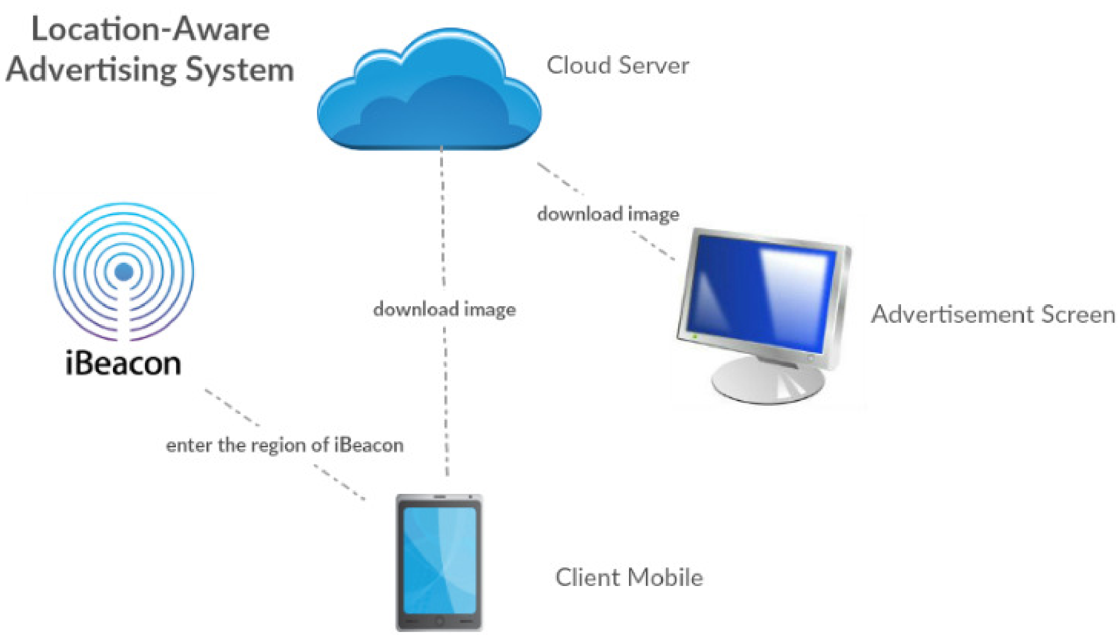

Figure 1.1: Illustration of the Location-Aware Advertising System

1.3 Organization

Chapter 2 introduces the background and related work about location-aware system. This chapter will focus on location based services and Bluetooth low energy technology. The concept and implementation of the system are presented in Chapter 3. The system will be introduced in three aspects: iBeacon, server and mobile application. Chapter 4 analyses the performance of the system. The analysis includes the accuracy of location information, the network delay and their effects on the system. Finally, the summary of the thesis is given in Chapter 5.

Chapter 2

Background and Related Work

In this chapter, we will introduce the current status of Location Based Service which includes the concept of BLE. Then, other research about location based services is briefed in the following section.

2.1 Location Based Service

The location-aware advertising system is a kind of location based service. The location could supply more information for advertisers to match the potential customers. Location based service is a mobile service enhanced by position information with Internet or wireless communication[3]. In outdoor situations, the cellular network or GPS could be utilized to provide position information. While in indoor environments especially in high buildings, the cellular network or GPS may not function well. Bluetooth is a solution for such short-range communication in indoor environments. In our system, we adopt a more promising Bluetooth solution: Bluetooth Low Energy.

2.2 Bluetooth Low Energy

The LBS needs location information to drive the application. For the short-distance communication or positioning in indoor environments such as buildings and supermarkets, the Bluetooth represents an ideal choice. At the same time, the energy consumption is also an important factor when we design the system. The system should be able to sustain for a long time on a single charge or not consume too much electricity per day. To achieve both of the above, Bluetooth Low Energy technology becomes our first choice. Bluetooth Low Energy is an emerging wireless personal area network technology designed by BSIG(Bluetooth Special Interest Group)[12]. BSIG lists the markets for BLE include health care, smart home, sports and fitness. The three main advantages of BLE are:

- Low price and mini size.
- Low energy consumption but the same range as classic Bluetooth, some BLE devices could reach 100 meters or further. A button cell battery could provide a life of months even years for BLE devices. [12] gives a study result from Aisle labs that a 1000mAh button cell battery makes proximity beacons function for 1-2 years. Usually the power consumption of BLE devices is 0.01-0.5 W. The reason is that BLE protocol just transmit small size data packet during communication and switch to sleep mode otherwise.
- The compatibility with tablets, computers and mobile phones. Most laptops, tablets and mobile phone have Bluetooth functions to interact with BLE devices.

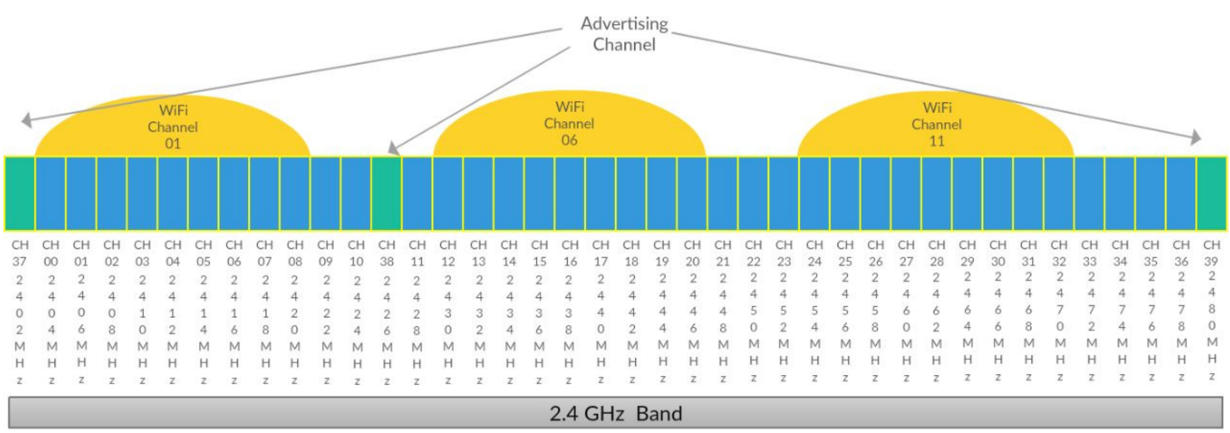

Figure 2.1: The Frequency Band and Channel of BLE

BLE also works in the same 2.400 GHz-2.4835 GHz radio frequency band as classic Bluetooth. The data rate is 1Mbits/s and all channels adopt GFSK(Gaussian Frequency Shift Keying) modulation with modulation index between 0.45 and 0.55. Figure 2.1 demonstrates the frequency usage of BLE. BLE operates on 40 channels and each of the channel has space of 2MHz [6]. The channels consist of two types of channels: data and advertising. The data channels which are blue colour in the figure are used for bidirectional communication between connected devices. The advertising channels are CH 37, CH 38 and CH 39 which are green colour in the figure, thus avoid the collision with the common-use WiFi channels 1, 6 and 11. The advertising channels are used to broadcast information, construct connection or discover devices.

A BLE device in advertising mode which means it only broadcast data, is called the advertiser. Although the advertising channels are separated from the WiFi Channels, the potential inference from other radio signals cannot be ignored. To achieve better performance and minimize the possibility of the channel being blocked, the advertising data is sent periodically on each advertising channel at one broadcast event as depicted in Figure 2.2.The interval consists of a fixed delay and a random delay. The random delay is generated by a pseudo-random range from 0ms to 10ms. This random delay is automatically added to the interval to avoid the collusion between different BLE devices. The advertising interval between two broadcast events is longer than 100ms, also it is later than the connection interval in case of connections established between BLE devices and other devices.

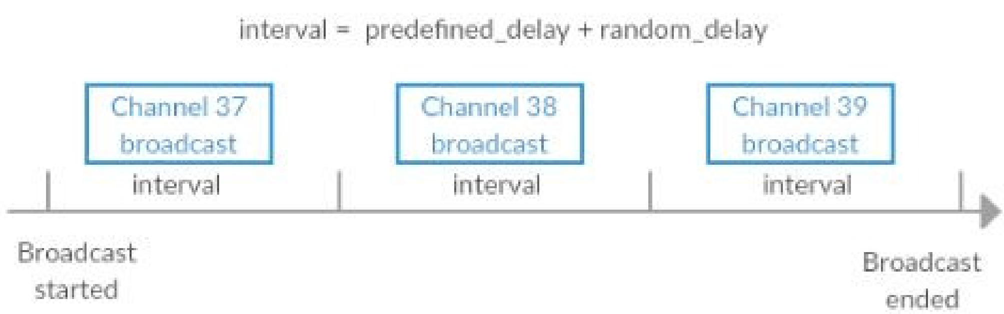

Figure 2.2: The Broadcast Sequence of BLE

2.3 Related Work

Not only in advertising, the location-aware system has broad uses in various places such as smart buildings, shops or hospitals. [10] demonstrates an iBeacon based indoor positioning system for hospitals to track the positions of patients. [8] shows an application to find suitcases in airports with location based services. Also, the location information could be part of the decision making system as illustrated in [9]. The position information plus the contextual information enable the system to target the user precisely and promote the advertisements to the customers efficiently. [1] proposes a revised iBeacon protocol to implement the occupancy detection in smart building. The potential market for location-aware system is huge and LBS requires innovative ways to fully explore its effect in systems and applications.

Chapter 3

Location-Aware Advertising System

In this chapter, each module of the location-aware advertising system will be introduced in the following sections. There are three modules. The iBeacon devices transmit signals of location. The server provides management of the advertisement. The mobile application is used to identity the specific region and download the corresponding advertisements.

3.1 iBeacon

The short range communication is a necessary feature for location-aware devices especially in indoor location systems. The low-energy wireless solution such as ZigBee and Z-Wave are widely used in applications requiring multi-hop networking, while Bluetooth Low Energy(BLE) provides a single-hop solution applicable to various space of use cases[6]. iBeacon is the implementation of the BLE beacon technology of Apple[11]. Since it was introduced by Apple in 2013,various vendors have made iBeacon compatible transmitters which called beacon[13]. iBeacon is an important component of the system because it provides the location information for the terminal to get proper content for users. In the following subsection, we will introduce its protocol and deployment.

3.1.1 iBeacon Protocol

The iBeacon devices are transmit-only[5]. They periodically transmit the data packets to the nearby clients. iBeacon data provide identifiers for users to inform the specific location

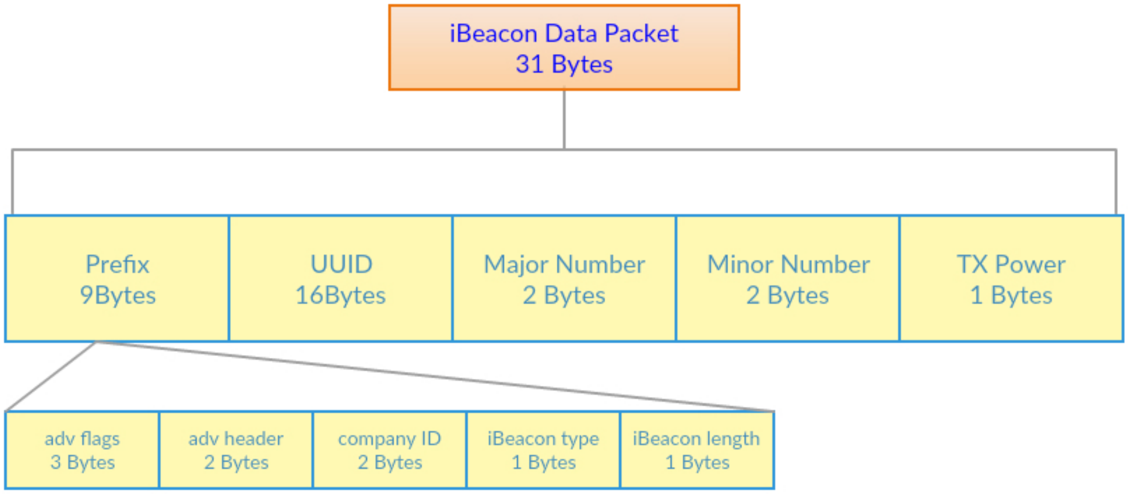

Figure 3.1: iBeacon Data Format

and for the cloud server to identify the request from local servers. Figure 3.1 shows the components of the data packet.

- Prefix contains five data sections. Flags indicate whether the iBeacon is capable of working in general discovery mode or low-energy mode or non-low-energy mode. The header tells that the frame is manufacturer-specific data. Company ID gives the company identifier. Type indicates whether the iBeacon is a proximity beacon. Length means the length of the remaining data.
- UUID is the abbreviation for Universal Unique Identifier which is used to distinguish the iBeacon from others and indicates the organization the iBeacon belongs to. UUID is usually generated by a random number with current time and the identifier of the generator.
- Major Number is used to identify the specific group the iBeacon belongs to.
- Minor Number is used to identify the iBeacon in the specific group.
- TX Power is the measured signal strength at 1 meter from the device. The value is called RSSI(Received Signal Strength Indication). As the strength decreases as the device gets further, we can calculate the distance between device and iBeacon.

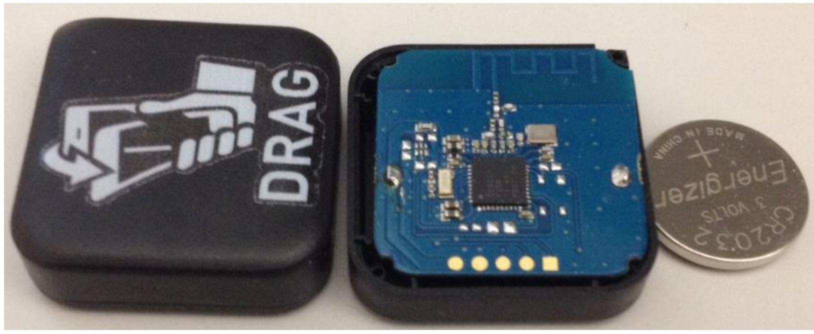

Figure 3.2: The iBeacon Device

Usually the value of data is predefined, while some iBeacon devices have methods to modify the value of data. The mobile or other devices with Bluetooth functions could receive the data packet. Then the terminal will calculate the distance to the nearby iBeacon and identify them. These information enables the terminal to do the related tasks. The detail will be discussed in the Mobile Application section.

3.1.2 Deployment

The BLE is based on 2.4 GHz frequency and the signal is subject to attenuation by physical materials or structures[2]. Various objects such as walls, boards, doors, or even human body could lessen the signal strength. The location accuracy will diminish when the signal strength is affected. For indoor advertising systems. The devices could be distributed at corners and adhered to the wall to make the signal cover the entire room. Figure 3.2 shows the iBeacon we use in the system. If the advertising interval is 100ms, the coin cell battery could provide 1-3 months life for the iBeacon. If the interval increases to 900ms, the ibeacon's life could increase to 2-3 years[13]. Therefore, we can leave the ibeacon alone once it is set up. Figure 3.3 shows an example of iBeacon layout in an office. iBeacon devices are distributed to avoid the physical surroundings which block signals.

3.2 Server

The content of advertisements is stored in the cloud server. The cloud server may distributed the advertisements to the local servers and local servers will arrange the display

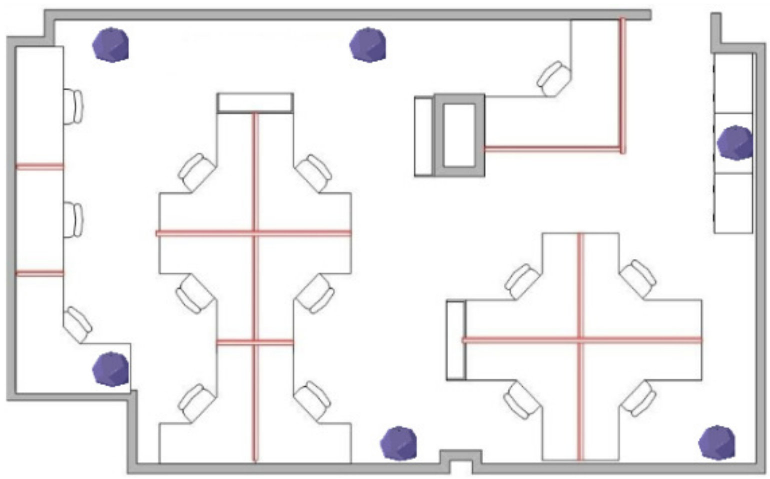

Figure 3.3: An Example of the iBeacon Deployment in an office

sequence of the advertisements. This section is focuses on the communication between the server and terminal.

3.2.1 Synchronization

For a billboard, when the displayed advertisement is static we just download the advertisement on the screen directly according to the identifier of the iBeacon. While the situation will be a bit complex when the advertisements are displayed in a round-robin fashion. The identifier is not enough to pinpoint the advertisement for user we want to download at the specific time. An ordinary method is sending the current time to the server and finding the advertisement displayed at that time, but the delay will be a problem as the increase of users grow. To improve the accuracy and alleviate the communication load between server and terminal, a simple but effective method is to synchronize the server with a predefined clock. A good choice is the Greenwich time which could be easily acquired from the network. Figure 3.4 gives the illustration of synchronization. When we want to download the advertisement, the terminal will calculate the index of the advertisement based on the current time and download. In the servers, every advertisement is assigned an index and displayed as the order is given by Eq.(3.1). t_{now} is the the current time based on second, t_{start} is the start time of display, num is the total number of advertisements and interval is the display interval of each advertisement. When the downloading is triggered, Eq.(3.1) will be applied to calculate the index of the advertisement on the terminal. Figure 3.5

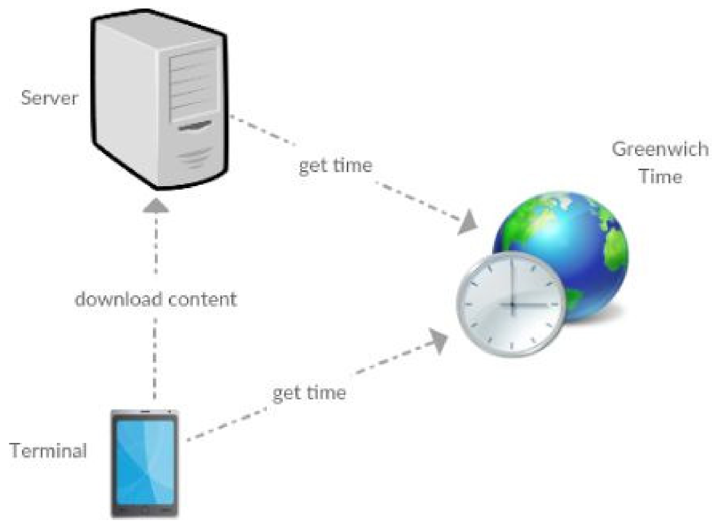

Figure 3.4: The Illustration of Synchronization

shows the interaction between mobile and servers synchronized with Greenwich time. In mobile applications we use the drag action to trigger the downloading, the details will be discussed in the Mobile Application section.

$$index = [(t_{now} - t_{start} + 1) \quad \text{mod} \quad (num * interval)] \quad / \quad interval \tag{3.1}$$

3.3 Mobile Application

In this system we developed the Android application for terminal devices and the concept is same for other mobile operating systems. The mobile application provides user interface to help the user interact with the system. The application is responsible for iBeacon signal detection, user command recognition and advertisement acquisition. To achieve the above function, the mobile application consists of three components: iBeacon detection, hand gesture detection and asynchronous downloading. The details are explained in the following subsections.

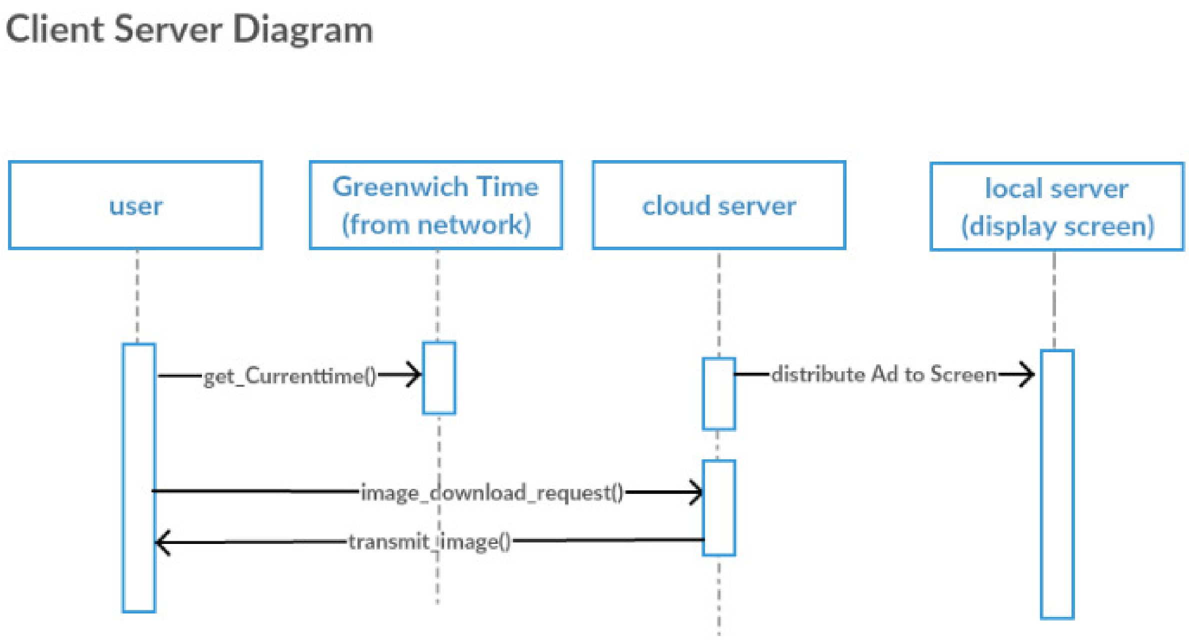

Figure 3.5: The Illustration of the Interaction Between Client and Server

3.3.1 iBeacon Detection

As a location-aware system, the positioning function is the significant part of the mobile application. Current mobile devices commonly have hardware support for BLE. The operating system iOS 5 and higher versions support BLE as well as Android 4.3 and higher versions. Thus, it is convenient for developers to develop the positioning function. The distance between iBeacon and terminal could be categorized into below different levels:

- Immediate: The distance is less than 0.5 meters.
- Near: The distance is within 0.5 meter to 3 meters.
- Far: The distance is within 3 meters to 50 meters.
- Unknown: The signal of the iBeacon is lost.

Figure 3.6 shows the range of signal emitted from a typical iBeacon device. The common iBeacon reaches up to 40-70 meters, some long range iBeacons could reach 450 meters[13].

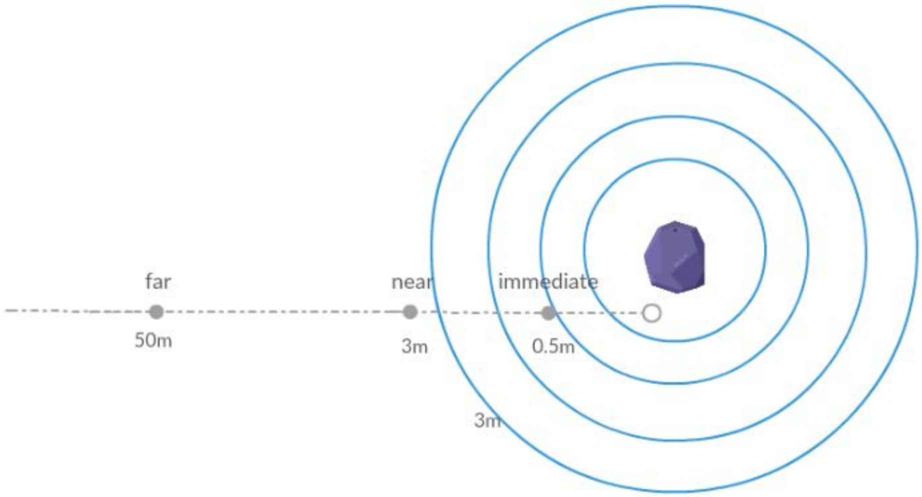

Figure 3.6: The Range of the iBeacon

The terminal device will turn on Bluetooth during the activity of the application. When the user enters into the range of the iBeacon signal, the terminal will begin to parse the ibeacon data packet. In the iBeacon Protocol subsection, the data packet of ibeacon is explained in details. Usually the user is in the near range of iBeacon because it is often used in shops, hotels, or hospitals where 0.5-3 meters is an appropriate distance for users to locate the intended position or articles. Also, there are many iBeacon transmitters deployed in such places, the overlap signal will be a problem for terminals to pinpoint the nearest iBeacon if any two transmitters are too close. In application, we use Android iBeacon Library to parse the data received from iBeacon. First, we have to find the nearest ibeacon to the user with the TX Power in the iBeacon data packet. The transmit power may vary greatly in different environments. The Android iBeacon Library uses an approximate formula Eq.(3.2) to compute the distance between the terminal and iBeacon device, where rssi(ratio of the iBeacon signal strength) is the parameter given by the terminal device. We choose the one which has the smallest distance value as the nearest iBeacon. After that, we get the UUID as well as Major Number and Minor Number to identify the specific iBeacon to execute the corresponding tasks.

$$distance = \begin{cases} ration^{10} & ration < 1 \\ 0.89976 * ration^{7.7095} + 0.111 & ration \geq 1 \end{cases} \quad ration = rssi/txpower \tag{3.2}$$

Figure 3.7: The Motion Direction of Mobile

3.3.2 Hand Gesture Detection

To improve the user experience, we designed just one single action for the interaction between human and system. The action is a simple drag action. The motion of the hand can be decomposed into the components of motion in three directions[14]. To recognize the gesture of the users, the accelerometers of the smart phone is utilized to measure the acceleration of three directions.Figure 3.7 shows the three directions of the accelerometers in mobile. We use Eq.(3.3) to calculate the total acceleration of the mobile, where A_x^2, A_y^2 and A_z^2 represent the value of acceleration of X, Y and Z axis given by accelerometers. To check whether the action happened, a straightforward method is to measure the difference between the acceleration $\overline{A_{t1}}$ at time t1 and the acceleration $\overline{A_{t2}}$ at time t2(t2-t1 $>$ t, t is the minimum interval). As the Eq.(3.4) shows, when the difference is larger than the threshold A_T, we can assert that the drag action has happened. Drag is the action to put the mobile closer to the user, thus a more accurate method is to the measure the variation of acceleration on Y and Z axis as the Eq.(3.5). When the application starts, the gesture detect thread is activated to listen for the drag action event.

$$\overline{A} = \sqrt{A_x^2 + A_y^2 + A_z^2} \tag{3.3}$$

$$\left|\overline{A_{t2}} - \overline{A_{t1}}\right| > A_T \tag{3.4}$$

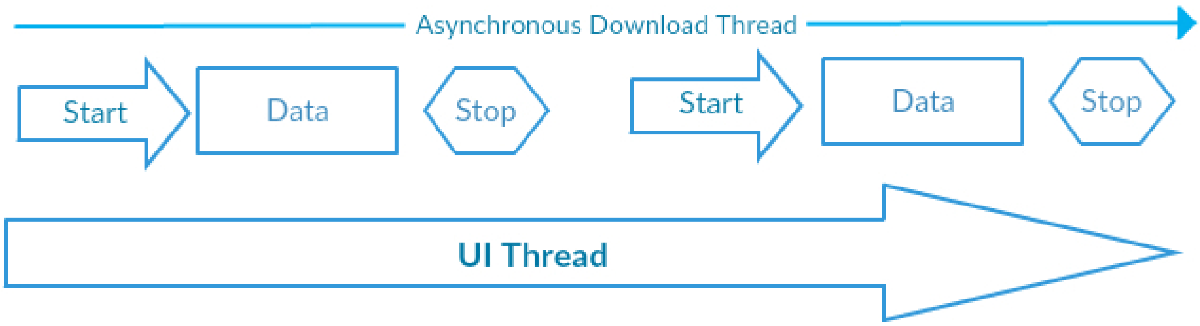

Figure 3.8: The Illustration of Asynchronous Downloading

$$\sqrt{A_{yt2}^2 - A_{yt1}^2} + \sqrt{A_{zt2}^2 - A_{zt1}^2} > A_T \tag{3.5}$$

3.3.3 Asynchronous Downloading

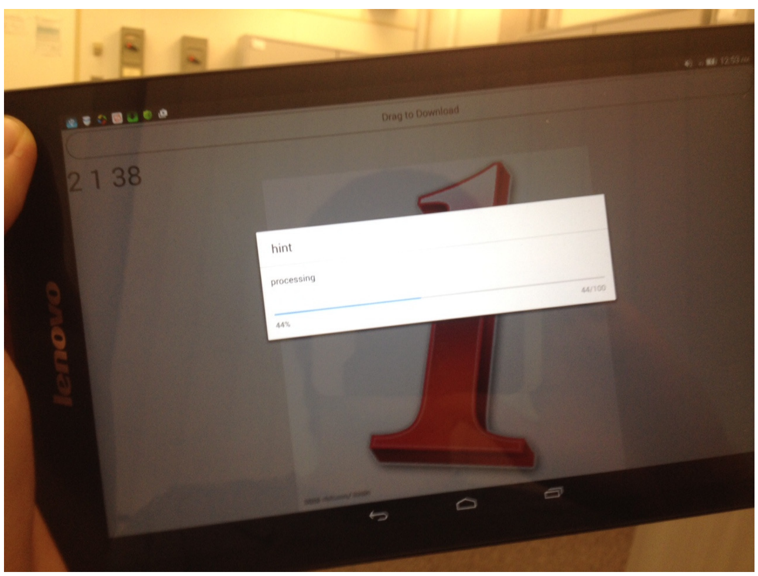

Figure 3.9: The Downloading Process

In Android application, at least one main thread is created when the MainActivity class is created. The main thread which is also called UI thread is mainly for generating the

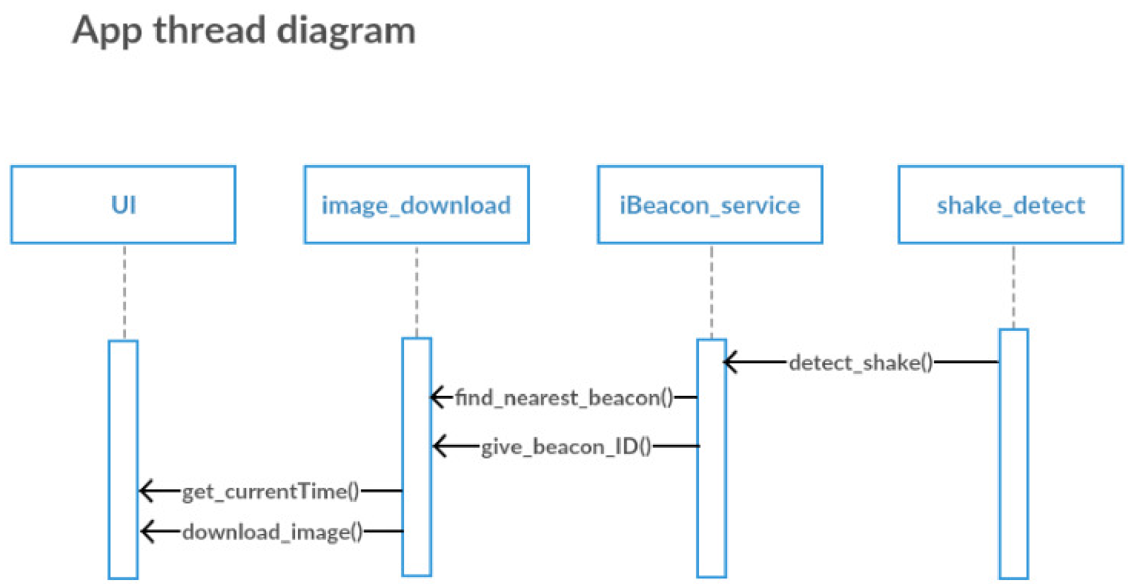

Figure 3.10: The Illustration of the Mobile Application Threads

user interface: drawing pixels on the screen, accepting the command from the user and launching other threads or activities. The application is active to the interaction with the user, thus the function which needs resources(time, network) inside MainActivity may not be executed before the end of the main thread. If the function delays the UI thread more than 5 seconds, the application will give the ANR(Application Not Responding) and then close. To relieve the main thread from the long-time operations or tasks[7], Android designed the asynchronous task to handle the long-time operation in background threads. Figure 3.8 gives the illustration of asynchronous downloading. The downloading thread will execute the downloading task in time slots to avoid blocking the main thread. The results will be send back to the main thread to display on screen after the completion of downloading. Figure 3.9 is the downloading process of our mobile application, to achieve the better user experience we use a progress bar to indicate the downloading process. The AsyncTask class is a helper class in Android to perform asynchronous tasks, it abandon the generic threading framework to make the thread manipulation easier. There are four steps to execute the AsyncTask:

- onPreExecute: this step is completed on UI thread to set up the environment for the following tasks.

- doInBackground: this step is performed immediately after the onPreExecute on the background thread to execute the tasks.
- onProgressUpdate: this step is invoked on UI thread to display the progress of the tasks on the background thread.
- onPostExecute: this step starts after the background tasks are finished and handles the results return from the background tasks.

After the four steps, the results are published to the UI thread. AsycncTask is used for the tasks which takes seconds and the advertisement downloading task meets this requirement.

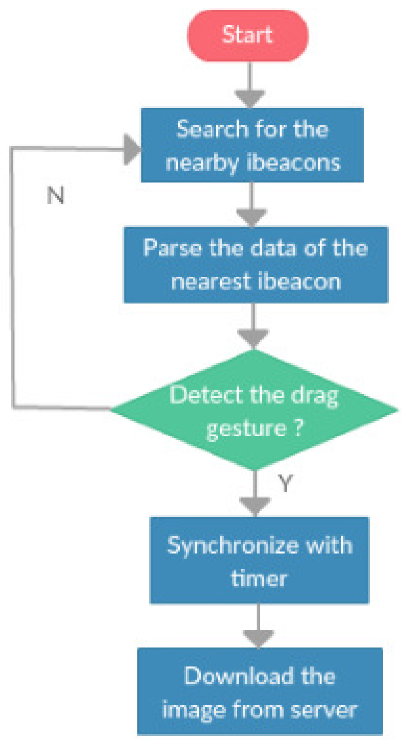

Figure 3.11: Software Design of the Application

3.3.4 Summary

The above are components of the iBeacon based location-aware system. Figure 3.10 shows the communications between threads and Figure 3.11 gives the flowchart of the software design. The mobile application is the most scalable part of the system and its architecture is clear and straightforward. In the future development, more features such as social functions could be added to the mobile application.

Chapter 4

Experiment

In this chapter, we will demonstrate the performance of the iBeacon based location-aware system. Figure 4.1 shows the devices of the system. In the experiment, we used a laptop as the local server as well as the billboard and an Android tablet as the terminal device. The advertisements are displayed on the screen and the user operate drag action on terminal device to download the advertisements. In the following sections, we measure the accuracy of iBeacon and the delay between server and terminal to the get the analysis of the system.

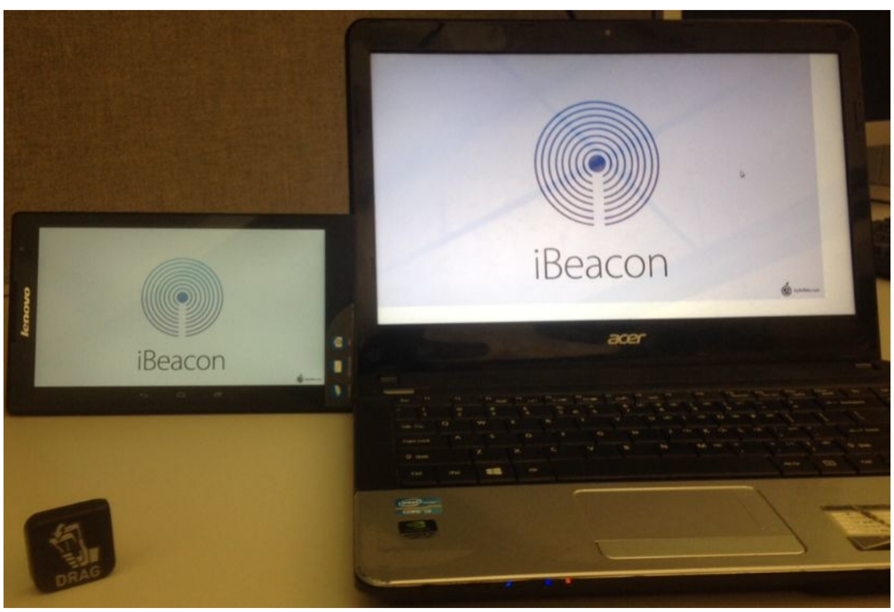

Figure 4.1: The Demonstration of the Location-Aware Advertising System

4.1 The Deployment of System

We deployed our system in our office. The size of the office is about 20 square metres. Figure 4.2 shows the detected iBeacons in the experiment. There are totally five active iBeacon devices which are enough for the size of the office.

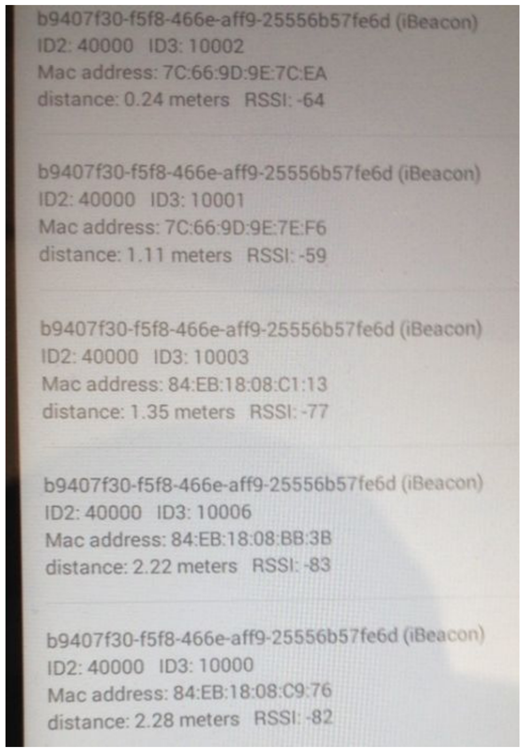

Figure 4.2: The Detected iBeacons

The identifiers are shown above to the region of each iBeacon and they also represents the index of advertisements for downloading. The signal strength of the iBeacons are powerful enough to cover the entire office. The billboard(in this experiment it is the laptop) could be placed anywhere in the room, we placed it in front of the door to achieve a better user experience. Figure 4.3 exhibits the layout of iBeacons in the office. The left side of office and the right side are similar. We adopted an isosceles layout to ensure the users were closest to at most two iBeacons and find that the mobile application was able to find the nearest ibeacon in the experiment. A user walked around the office and downloaded the advertisements in different positions to test the system. The public WiFi was employed to be the network service to reduce the cost and the system functioned well during the experiment. Next, we give the performance and analysis of the system.

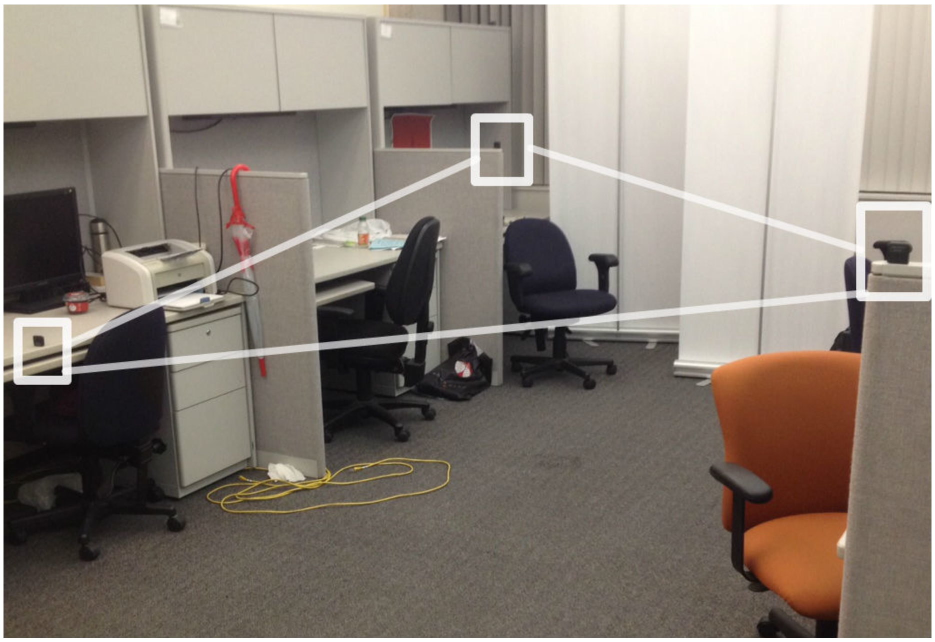

Figure 4.3: The iBeacons in an Office

4.2 Performance and Analysis

In this section, the performance of the system are tested from two aspects: accuracy and delay. The accuracy is the ability of the system to locate the user from a specific distance. Delay is the probable time interval between synchronized mobile applications and the server. Both of the parameters determine whether the system is capable of pushing the required advertisements to the user. We also provide our solutions to enhance the accuracy and cut delay.

4.2.1 Accuracy

When the user walked into the signal region, the mobile application searched for the nearest iBeacon. In the previous chapter, we explained that the terminal sensed the signal strength to calculate the distance between the user and iBeacon according to an approximate formula. To sample 300 distance data, we start from 0.5 meters away from a specific iBeacon and move 0.5 meter further every 60 seconds. The distance calculated by the mobile application is recorded every second. The test results are shown in Figure 4.4.

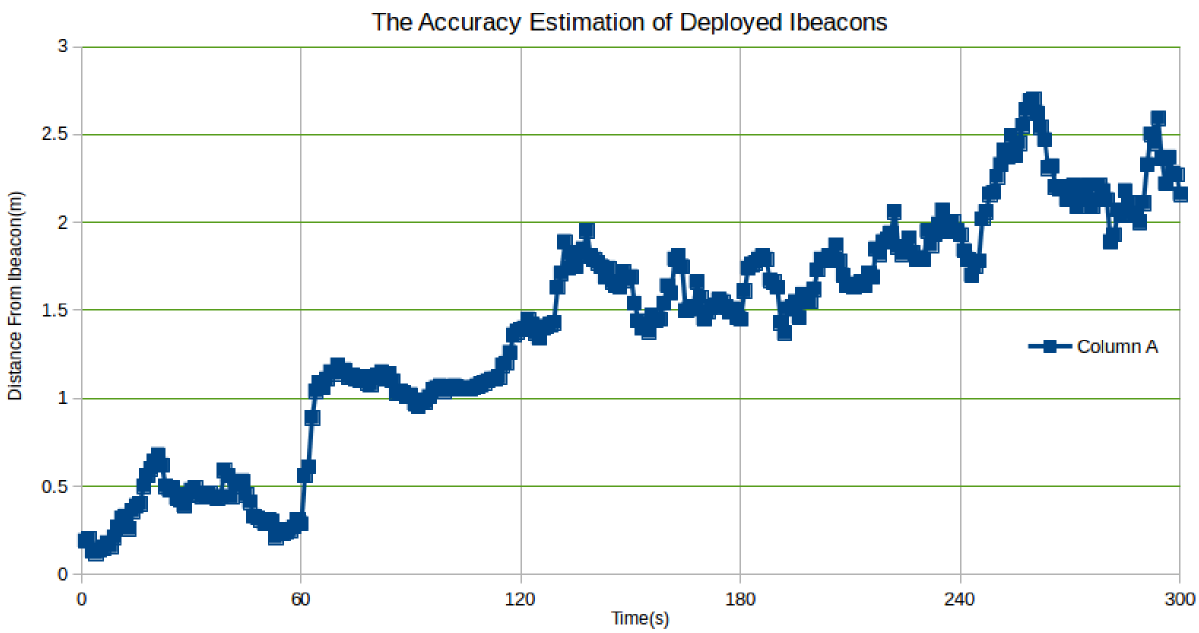

Figure 4.4: The Accuracy Estimation of Deployed iBeacons

From the result, we could see that the distance read from 1 meter away has the best accuracy and the system also performs well from 0.5 meter away. However, the distance read from 2 meters or further has a greater error. From the figure, it also shows that the application tends to underestimate the distance as the distance increases. The greater distance and more obstacles make the signal strength incurs more attenuation, while this accuracy is enough for an indoor location. Even though the distorted distance has little effect on identifying the nearest iBeacon from the experiment, we still recommend to put iBeacon devices with a separation around 2 meters in small spaces such as offices to achieve better accuracy. Thus the user who enters into the signal region could be precisely positioned. The recommended layout is displayed in Figure 4.5. The triangle layout is also scalable for large places. For example, the regular hexagon design of cellular network could also be applied to iBeacon placement in supermarkets or museums.

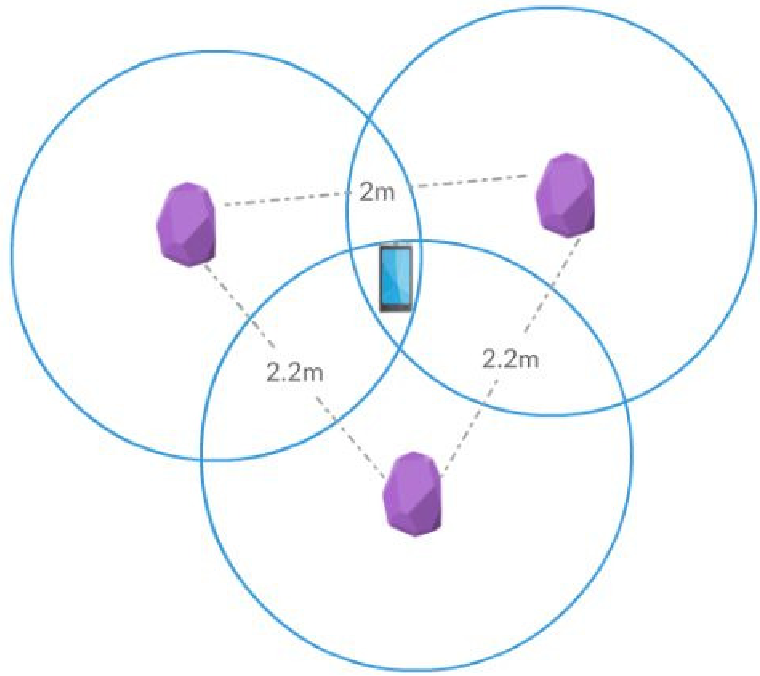

Figure 4.5: The Layout of iBeacon in a Small Space

4.2.2 Delay

From the previous chapter, we introduced the method to synchronize mobile applications and servers with an outer clock to lessen delays and alleviate the communication load between server and terminal. However the delay cannot be avoided in reality. Thus the index of advertisements calculated by mobile application may be different from the index computed by the server. Figure 4.6 shows the factors of delay. The main factor is the network delay which is determined by the network service provider. Although the network delay is out of our control, we still could measure or monitor the network delay and deduct or add to it to compensate for the calculations.

Figure 4.7 shows 150 data point we sampled from the download process. In this experiment, we adopted Greenwich time as the synchronization source, but we found a 100 milliseconds delay between the Greenwich time received by the terminal and server. This may be caused by a network delay but it is not a big problem. Most delays are between 100 milliseconds and 200 milliseconds and we could view it between 0 millisecond to 100 milliseconds due to the delay of Greenwich time. It is tolerable for such systems and we could download the correct advertisement on the screen. Some outliers may suffer from longer routing. In addition to the common network delay, the server side will face concurrency issues when the users increase. In such situations the delay may increase rapidly. It needs to optimize the queuing mechanism as well as buffer to short the delay.

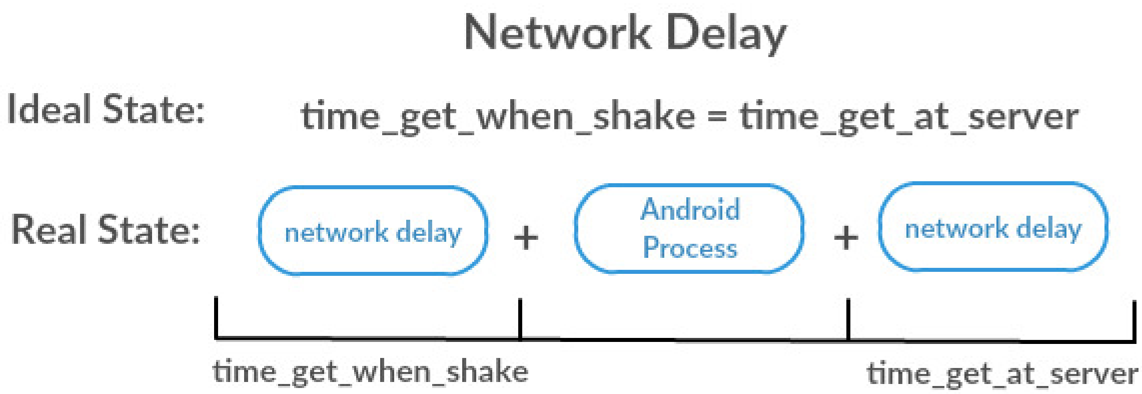

Figure 4.6: The Delay Factors

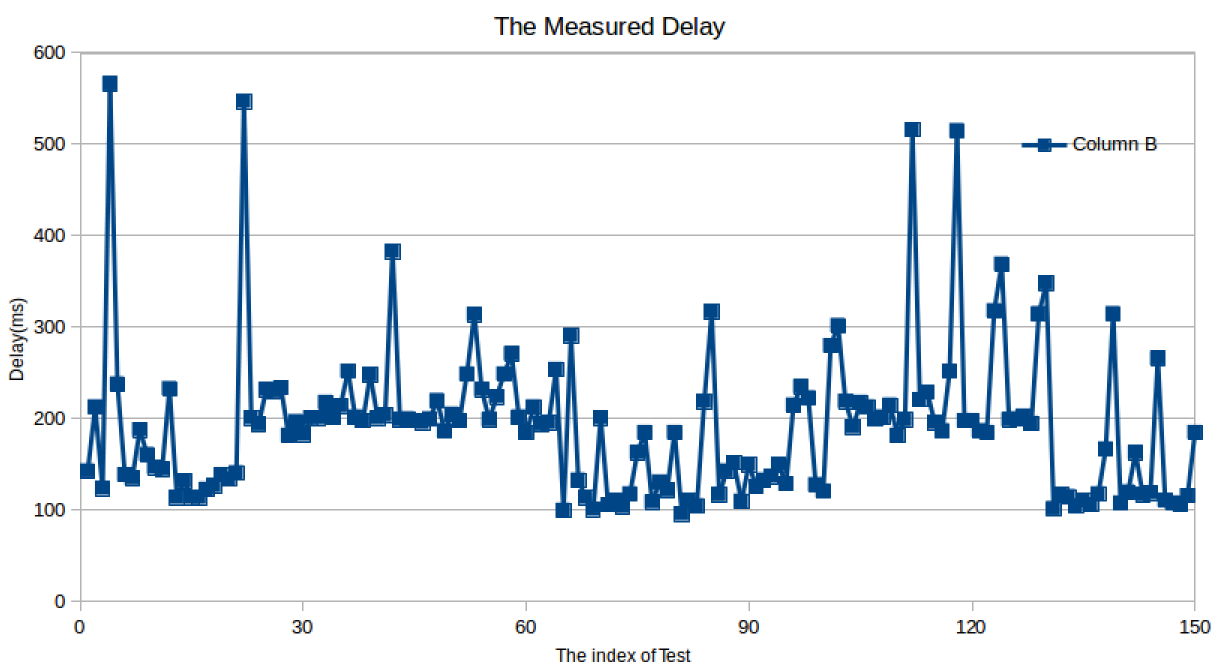

Figure 4.7: The Measured Delay Between Terminal and Server

4.3 Summary

In this chapter, we gave the deployment of the system and evaluated its performance with delay and accuracy. The location-aware advertising system is easy to deploy and works well in indoor environments. The iBeacon achieved its best positioning capacity around 1 meter and a triangle layout was introduced to place the iBeacon. The whole system is immune to the common network delays, but the delays may be a bottleneck for a large volume of users.

Chapter 5

Summary

Modern commerce requires innovative advertising methods. The user usually walks around in some areas to explore new items. Hence, the location information is a good assistance for advertising methods. In this thesis we presented a location-aware advertising system which was able to locate the nearby customers and push advertisements efficiently.

5.1 Thesis Summary

This thesis proposed an iBeacon based location-aware advertising system. The system consists of the mobile application, server, iBeacon and could be deployed in small space area such as offices or stores. The iBeacon devices provide positioning signals for mobile applications to recognize the specific region. The Mobile application will detect the drag action of users to download advertisements on billboards. The server and mobile application are synchronized with Greenwich time to alleviate the communication load. Performance analysis shows that the positioning accuracy achieved its best around 1 meter and the synchronization delay was between 100 milliseconds and 200 milliseconds. The whole system is reliable and user friendly.

5.2 Future Work

The system proposed in this thesis just has the basic function to display and push advertisements to users. There are two aspects in this system that need improvement: server and user interaction. For the server side, it needs a better queuing mechanism to handle a large volume of users and decrease the delay. For user interaction, more hand gestures could be detected to manipulate the display sequence of advertisements. A higher version of this system will display video on billboard and users will be able to download the snapshot at any time.

5.3 Conclusion

A iBeacon-based location-aware advertising system was proposed in this thesis and it is easy to deployed. As the development of technology and commerce progresses, the location-aware services such as advertising systems and smart buildings will become more popular.

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