Research on Application of Beacon-based Location Technology in American Universities

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Abstract. With the popularity of smart phones, whether we are driving or walking, we are accustomed to using GPS for outdoor navigation. However, when you are in a library, shopping mall, etc., the GPS signal is blocked and the system will not be able to navigate for you. Then we need a technology that can provide indoor navigation. Beacon is a near-field sensing technology based on low-power Bluetooth technology that can be used to provide indoor positioning services for users with the Bluetooth capabilities of mobile phones. This paper describes the Beacon positioning technology principle and the application of Beacon-based location technology in American universities. In a university library, lab, conference room and other indoor environments, Beacon-based positioning technology can provide specific information transmission, indoor navigation, book recommendation based on big data analysis, and attendance check-in functions.

1. Introduction

With the continuous development of information technology, the informatization level of universities is constantly improved. Digital campus construction has become increasingly perfect, and most universities have started the construction of smart campus. An important feature of a smart campus is the ability to intelligently perceive the environment in which the user lives. It can provide users with location-based personalized services based on the physical environment in which the user lives. Perceiving the user's environment can be understood as user positioning. The core issue is how to calculate and determine the user's location through technical means. Currently available positioning technologies include ZigBee, RFID, WIFI, and Beacon. In the related literature, there are comparatively detailed comparative studies on the implementation costs, positioning accuracy of these kinds of positioning technologies, which are not described in this paper. This paper focuses on Beacon positioning technology principle and the application of Beacon positioning technology in American universities. We look forward to providing some useful reference for your peers in the implementation of similar projects.
2. Beacon-based positioning technology

2.1. Overview of Beacon-Based Positioning Technology
Beacon is a near-field sensing technology based on Bluetooth low energy technology. The technology was originally launched by Nokia, but the scope of application is very small. In 2013, Apple released the iBeacon protocol based on the Bluetooth 4.0 low-power protocol. They gradually extended this technology to more applications. The biggest advantage of Bluetooth low energy over traditional Bluetooth is a 90% reduction in power consumption. In a study by several different Beacon vendors, the battery life can reach 24 months. At the same time, the transmission distance increases, and the security and stability increase.

Pairing work is required in general Bluetooth device impressions. The Beacon does not need to be paired because it transmits signals using the Bluetooth broadcast channel. We do not need to always open the APP to receive the Beacon signal. As long as the APP is installed and Bluetooth is turned on at the same time, the Beacon-based application can be awakened in the background. At present, Beacon technology is mostly used for indoor positioning. The information system can provide personalized information services based on the user's location.

2.2. Beacon-based positioning technology application system
Beacon does not have the traditional data transmission function. The Beacon base station only pushes location information. The data format [1] is shown in the figure 1. If the APP wants to communicate with the server to implement customized functions and obtain customized data, it needs to turn on other data communication, such as WIFI and 4G.

![Figure 1. Data format of the Beacon](image-url)

UUID is the ID that distinguishes different Beacon devices. For example, multiple Beacons are currently distributed in a certain area of a store to form a "chain" for providing customers with specific services. Then the Beacon device belonging to the same "chain" will be assigned the same UUID. The dedicated application designed for this "chain" will use this UUID in the background to scan to the Beacon device in this "chain".

Major is used to identify related Beacon devices as a group. For example, all Beacon devices in the same store will be assigned the same major number. In this way, the application can know which store the customer is in.

Minor is used to identify a specific Beacon device. For example, each Beacon device in a store has a unique minor number so that we can know where the customer is located in the store.

TX power is used to determine the distance between the user client and the Beacon device. According to this value, not only information such as near/away/out of range can be obtained, but also the distance to the meter can be obtained.

RSSI [2, 3] is a common positioning technology that can be applied to Beacon-based positioning systems. RSSI is an abbreviation of received signal strength indication. By measuring the signal strength from the Beacon Bluetooth signal transmitter received by the user terminal, we can calculate the distance between the user and the transmitter. If there is only one Beacon Bluetooth signal transmitter, the user terminal will be positioned on the circumference centered on the transmitter.

When there are multiple Beacon Bluetooth signal transmitters, we can calculate the distance between the user terminal and each Beacon Bluetooth signal transmitter through RSSI. Through these distance values, we can calculate the precise location of the user terminal. In practical applications, we often use fingerprint positioning methods [4]. We know that the characteristics of wireless signals are related to geographic location. In theory, each geographic location corresponds to a unique wireless signal signature.
The wireless signal feature can be used as fingerprint information for the location. Therefore, we can see that each set of characteristic wireless signals corresponds to a unique geographic location. In an actual case, the Beacon-based fingerprint positioning process is divided into an offline acquisition phase and an online positioning phase.

During the offline acquisition phase, the engineer will collect the signal strength from the different Beacon Bluetooth signal transmitters at each location in the target environment by the handheld Bluetooth signal receiving device. The signal strength from the Beacon Bluetooth signal transmitter #1 is $RSS_1$. The signal strength from the Beacon Bluetooth signal transmitter #2 is $RSS_2$. The signal strength from the Beacon Bluetooth signal transmitter #m is $RSS_m$. We form a one-dimensional vector of all collected $RSS$ values. The vector is $(RSS_1, RSS_2, RSS_n)$. At the same time, the engineer will record the coordinates (x, y) of each position. They associate this coordinate with the one-dimensional vector to form a two-dimensional matrix. This two-dimensional matrix is $(x, y), (RSS_1, RSS_2, RSS_n)$. After the engineers have collected the coordinates and signal strength information of all positions, the two-dimensional matrix is stored in the database. This forms the location fingerprint database for the target environment. The position fingerprint acquisition process is shown in the figure 2.

![Figure 2. Position fingerprint acquisition process](image)

During online positioning, the system topology is shown in the figure 3. The user terminal is connected to the location calculation server through the mobile internet. At the same time, the location calculation server is connected to the location fingerprint database server.
The user terminal first records the RSS value received from each Bluetooth signal transmitter. The user terminal sends these RSS values to the location calculation server over the mobile Internet. The location calculation server compares the RSS value in the location fingerprint database server with the RSS value from the user terminal. Then, the coordinates \((x, y)\) of the user's location can be calculated in the database to complete the positioning [5, 6].

3. Application of Beacon-based Positioning Technology in American Universities

3.1. Pushing of specific messages

When a reader enters the library, once the reader enters the coverage of the entrance Beacon Bluetooth signal transmitter, the system will automatically send a welcome message to the reader. The content of this information may include a new book recommendation, a recent library activity schedule, and so on. After the system has obtained the reader's identity information, it can push personalized information [7] to the reader, such as overdue reminder of the books, appointment reminder to the books, appointment reminder for small training room and so on. At the same time, the system can also push events for individual users based on past records of participating in library activities.

When the readers enter the self-service area, the system will push the introduction of the self-service borrowing equipment, self-service photocopying equipment and self-service payment equipment use processes and FAQs to the readers.

When the user enters a certain building, once the user enters the coverage of the entrance Beacon Bluetooth signal transmitter, the system will automatically send the user instructions on how to access the network or computer. When the user enters a laboratory's Beacon Bluetooth signal coverage, he can receive a brief introduction and equipment status of the laboratory. When the user enters the Beacon Bluetooth signal coverage of a classroom, he or she can receive the current course information or the status of the classroom.
3.2. Indoor navigation
In a huge university library, you often worry about getting lost. If we are outdoor, we can use GPS to navigate. However, GPS will lose its function indoors and it will not be able to navigate. The Beacon-based positioning technology provides us with an indoor navigation solution [8]. Nearly 300 Beacons have been installed in the University of Oklahoma Library, which contains 500,000 square feet of resources, and provides mobile APP. This helps students and other library users through the terrifying terrain. When the student turns on the Bluetooth function of his smartphone, he will send the signal strength of the surrounding Beacon device it receives to the server. The server can calculate his position in real time. The APP can be used for indoor navigation. Students can also view the detailed map of the library through the APP. Students can use it to find specific rooms in the library. Based on his location, the system can plan a reasonable route for him and guide him to the room. When a student needs to find a book, he can also use the navigation function of the APP to coordinate with the library's RFID book positioning system and instruct the student to reach the corresponding bookshelf.

3.3. Books promotion based on big data analysis
The Beacon Bluetooth transmitter can detect the user's location when the user searches for a book in some area of the library. For example, in the area of information technology books, the system will push the information of books with a TOP10 borrowing rate to the users. The system can record the user's staying frequency, staying time and reading books on a bookshelf or a reading room. After a long period of accumulation, these data can be used for the user's reading behavior big data analysis. It can reflect the user's reading habits, accurately grasp the reader's reading preferences, and thus more accurate to promote books to users. Through the analysis of university users' reading behavior, it can also provide data support for book purchase.

3.4. Attendance check in
In university classroom teaching, academic conferences, and activities, it is often necessary to sign in. The commonly used check-in methods include manual check-in, QR code check-in, and campus card check-in. However, these check-in methods take too long and the user experience is not good. If the Beacon device is deployed in classrooms and conference venues, the users can realize check-in without a sense. After the user opens the APP and turns on the Bluetooth function, he can receive the information from the Beacon device The APP will automatically sends this information to the server. The system can confirm that the user has arrived at the site and completes the check-in.

4. About Beacon-based positioning technology promotion
Some people may worry that users will refuse to turn on the mobile phone Bluetooth because of the battery standby time, so the Beacon-based positioning function will be difficult to promote. In the 3G era, the data flow fee of mobile phones is very expensive. Users often look for WIFI signals everywhere, and set the data communication function of the mobile phone to the off state. With the advent of the 4G era, the data flow fee of mobile phones has been decreased. Users no longer have to worry about the data flow costs, and they naturally maintain the opening of the data communication capabilities of mobile phones any time. We can imagine that in the future the mobile phone battery technology will be developed, users will not worry about the battery life, and they will certainly turn on the Bluetooth function any time. Since Bluetooth is turned on, users can get better services, and users will certainly be willing to open this function. Beacon-based positioning functions will become more and more popular.

5. Conclusion
This paper describes the application of Beacon technology in American universities. The main purpose is to share some experiences and provide an option for your peers in a specific project implementation plan. We know the technologies that can be used for indoor positioning also include RFID, WIFI, and ZigBee. We do not need to absolutely determine whether Beacon, RFID, WIFI, ZigBee and other positioning technologies is advanced and which is backward. Any kind of technology has its advantages,
and no one technology is applicable anywhere. We cannot simply make one or the other technical route choice. In different application environments, choosing the right technology or even a solution that integrates multiple technologies is the key to solving the problem.

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