Application of iBeacon in Indoor Positioning and Navigation

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Abstract. In recent years, with the development of new energy vehicles, the demand for indoor charging is increasing. In the construction and application development of large indoor parking lot, users' demand for location-based service is more urgent. At this point the indoor positioning technology appears to be very important. At present, indoor mainstream technologies include UWB, RFID, ZigBee, ultrasonic, inertial navigation, optical positioning, iBeacon, Wi-fi and geomagnetic, etc. Compared with other technologies, iBeacon technology has the advantages of low power consumption and strong compatibility. iBeacon positioning technology helps users find idle charging piles more quickly and conveniently. This paper will briefly introduce the application of iBeacon in indoor positioning and navigation and related algorithms.

1. Introduction
The technology selection of wireless indoor transmitting signal positioning includes sensor network, mobile terminal and positioning mode. Wireless indoor positioning is mainly through the sensor network system. Mobile terminals mainly include smart phones, smart terminals and laptops. The positioning method depends on the current indoor environment.

This paper will study the application of iBeacon positioning technology and the implementation of relevant navigation algorithms.

2. Outline

2.1 iBeacon Outline
iBeacon's power consumption is extremely low that a button battery can last up to three years. At present, the mainstream smart phones on the market can support bluetooth 4.0 very well, so iBeacon can easily play a role in these phones. When a user enters a store, the app on the smart phone can listen to the iBeacon device to receive push messages and special offers from the store.

In general, iBeacon system includes bluetooth terminal base station and intelligent equipment. The bluetooth terminal base stations are distributed in various locations of the positioning site, where the user receives the positioning signal and the RSSI value of the connection through the bluetooth terminal base station and the smart phone, so the distance between the user and the bluetooth terminal can be obtained through the triangular indoor positioning algorithm.

2.2 The Data Format of iBeacon
iBeacon standardizes the BLE data format, which contains four Major pieces of information, UUID,Tx-power, Major and Minor.

The UUID is a 16-byte string used to distinguish between different iBeacon devices. For example, if you set up an iBeacon device in a chain store, the terminal can know the chain store which the
The device belongs to from the UUID. The Major is a 2-byte string used to determine the specific ownership of the device. For example, a chain store has four iBeacon beacons in one of its stores, so these four beacons have the same Major. Minor is a special identifier for each device, or in the case of a chain store, where the iBeacon for one store has a different Minor. TX-POWER is defined as the signal strength exactly 1 meter away from the device, which can be used to judge the wireless signal distance between the device of iBeacon and the terminal. In the actual measurement application, due to the changes and fluctuations of wireless signal and other characteristics as well as complex environmental factors, the measured value of the wireless signal range of iBeacon is not very accurate. In the case of complex physical and spatial conditions, the definition and variation of the distance range measured are generally divided into four distance range values: immediate when the distance is less than 1 meter, near when the distance is from 1 meter to 3 meters, far when the distance is far, and Unknown when the distance cannot be judged.

3. System Implementation of iBeacon

3.1 System Brief
iBeacon system is one kind of system which based on indoor distributed system. Indoor distributed system technology is one system which make use of indoor distributed antenna communication system and ensure the signal emitted by the mobile communication equipment of the computer is distributed evenly in every indoor area, in this way, the computer can be controlled and guaranteed to have good indoor communication signals in each area of the indoor distributed antenna communication system. The purpose of indoor distributed system is to improve the coverage of indoor communication signal and the quality of communication and network. Indoor distributed system mainly consists of signal source and signal distribution system. Signal source mainly includes base station, repeater station, relay station and micro cell, etc. The main function of the signal distribution system is to distribute, amplify and spread the signal transmitted by the signal source, so that the signal transmitted by the signal source can be uniformly distributed in the coverage area.

3.2 Weighted Triangle Centroiding Algorithm
The bluetooth positioning system connects the bluetooth Beacon node through the network cable in the remote rf coverage unit of the distributed base station, and realizes the bluetooth back office management on the server side to remotely operate and monitor the bluetooth Beacon node. The functions of each component of the system are as follows: the main function of the bluetooth Beacon unit is to obtain the data needed for location sent by the mobile terminal device or to send the data needed for location to the mobile terminal device. The bluetooth device is directly connected with the remote RF coverage unit, meanwhile the bluetooth nodes in the bluetooth Beacon unit can be in series or parallel connection.

The main function of remote RF coverage unit is to realize the direct power supply to the bluetooth Beacon, and provide the link forwarding channel for the communication data between the bluetooth Beacon node and the extension unit, the channel can choose the extension unit of 232 serial communication mode, Add Bluetooth unit scheduling management function in the expansion unit, receive reverse positioning acquisition data and report to access unit, active detection of bluetooth beacons, firmware upgrade of bluetooth unit, receive bluetooth configuration management information and send it to bluetooth unit and other functions etc.

The access unit adds bluetooth back office management to the access unit and the communication forwarding route function, It mainly realizes receiving bluetooth escalation information from the extension unit and forwarding it to the back office and receiving back office configuration management information and sending it to the extension unit. Bluetooth back office management provides topology diagram display of bluetooth unit monitoring, online and offline status display, visualization of forward and reverse positioning monitoring, historical data display and export, building floor management, indoor map management, bluetooth device management and other functions.
3.3 System Function

Distributed bluetooth positioning system Forward positioning module Reverse positioning module Bluetooth back office management Historic records query. The main functions of the forward positioning module are positioning and navigation. The mobile terminal device used is the mobile phone. When a user enter into an unknown environment, first ensure the bluetooth launch of the mobile phone, open the mobile phone positioning APP to scan the surrounding bluetooth Beacon device and obtain the corresponding RSSI data packet and upload it to the server, The server side can calculate the user's location through the built-in positioning algorithm and return it to the positioning result visualization module of the mobile phone or bluetooth back office management system, The positioning result visualization module of mobile phone positioning APP or bluetooth back office management system shows the user's position in the map by combining the positioning result and map information. Users can also select the destination in the navigation mode page of mobile phone positioning APP for indoor navigation

The main function of the reverse positioning module is to monitor and find objects. The mobile device used is a bluetooth bracelet or a passive positioning mobile terminal device with embedded chip. When the user who carries the bluetooth bracelet or the item with the bluetooth chip enters the environment where the indoor bluetooth positioning system is deployed, the bluetooth Beacon device will scan the bluetooth bracelet signal and upload the RSSI data packet to the server side, the server side calculates the location of the user or item through the built-in positioning algorithm, the manager can check the location of current user or item through mobile phone positioning APP or bluetooth back office management system

The main functions of bluetooth back office management module are bluetooth device management, area management, visualization of positioning results and query of historical records. Bluetooth back office management system is implemented on the server side, by getting the RSSI data packets and combined with the server's built-in positioning algorithm, to calculate the user's location along with map information and return positioning results back to the result visualization module of mobile terminal and bluetooth positioning back office management system, at the same time the bluetooth back office system also can real-time monitor the state of bluetooth devices.

3.4 System Design

System design mainly includes server system, mobile phone terminal system and test system. The server system is used to process the positioning request sent by the user. The quality of positioning algorithm determines the rapidity and accuracy of map positioning, it also affects the user's experience, The calculation module of location fingerprint on the map usually performs a series of calculations based on the location fingerprint information uploaded by the user, and finally obtains the user's location on the map. In this calculation process, the accuracy of positioning and the application efficiency of a series of algorithms need to be fully considered. The location computing module is
placed on the server but not on the client side, not only to avoid the frequent update of map data from the cloud server side by the client side, but also to avoid the slow calculation caused by the user's mobile phone performance, and to some extent, the problem that the mobile phone side cannot store complex data can be solved. In terms of the client terminal, smart phones can sense the presence of iBeacon devices around with the help of their own bluetooth devices. In the whole process, there is no need to add other devices except the deployment of iBeacon devices.

4. Positioning Algorithm

4.1 Positioning Technology Brief
There are three general indoor positioning schemes: single-point positioning, two-point positioning and multi-point positioning

4.2 IBeacon Indoor Deployment
In the positioning environment based on iBeacon signal fingerprint, RSSI can be generally used to obtain the distance between iBeacon base station and the positioning point. There is a one-to-one correspondence between the RSSI vector and the two-dimensional geographic position vector. So the interior space can be divided into a number of small areas, each area has its own set of iBeacon vector, through the positioning algorithm can match out the precise information of position. iBeacon is a low power bluetooth device with 2.4GHz. Its signal is easily affected by the complex indoor environment, especially the blocking objects such as human body, door and wall. In order to improve the positioning accuracy, iBeacon equipment should be considered in the indoor deployment of the location problem. Due to the logarithmic relationship between iBeacon signal and distance, iBeacon should be kept relatively close to the user as far as possible when arranging iBeacon.

As shown in figure 2, the blue circle represents the iBeacon device location. Assuming that the area of region abcd in the two pictures is the same, the iBeacon density of the two deployment modes is the same, but the dispersion mode of deployment is different, so the distance between users in different regions and each iBeacon device is different. When the user moves from the abcd area of the second image to the bde area, the abcd-based positioning is changed to bde to improve the positioning accuracy.

4.3 Triangulation Positioning Algorithm
The triangulation positioning algorithm places three bluetooth terminals in the space where positioning is needed, and the location of the three bluetooth terminals is known, if the signal strength of a certain position in the space is known, the signal attenuation model can be established, according to the signal strength to calculate the distance from the location to the three bluetooth terminals. Use the signal strength of a mobile device at a certain location to estimate the distance to the nearby bluetooth
terminal, if the location of several bluetooth terminals can be determined, the location of the mobile device can be determined.

As shown in the following figure

![Triangulation location](image)

**Figure 3. Triangulation location**

### 4.4 Fingerprint Positioning Algorithm

Fingerprint positioning algorithm is used to solve the signal interference in a special indoor environment. In a complex indoor environment, the signal will be blocked by objects, resulting in many cases, the signal strength is not correlated with the distance, and the signal at a far distance from the signal source may be stronger. In this case, it is not appropriate to use triangulation positioning algorithm, but fingerprint positioning algorithm can be considered. The "fingerprint" in fingerprint positioning algorithm refers to a series of serial Numbers and coordinate information.

### 5. Path Planning Algorithm

#### 5.1 Dijkstra Algorithm

The algorithm of dijkstra adopts a greedy strategy at the beginning, its purpose is to declare two arrays a and b, a can be used to store the shortest distance from the origin to the vertices of each path, and b can be used to save the vertex with the smallest path weight among the vertices that can't be found. Initially, the weight of the origin is assigned to zero, and the b and a in the array have only one vertex. If one of the nodes has a directly unreachable edge, mark this edge and set the path weight of the other vertices to the unreachable value. Select the minimum value from the a array, and k will be the shortest path from the origin to the corresponding vertex, and add k to b. If the newly added vertex can reach another vertex, and the path length through that vertex to the other vertex is shorter than the direct path from the origin, then the value of these vertices in a is replaced. Finally, find the smallest value from a and repeat until b contains all the vertices of the graph.

#### 5.2 BFS Algorithm

BFS algorithm belongs to graph breadth first search algorithm. The idea of this algorithm is to take out all the adjacent nodes of a node and judge whether the adjacent vertices are terminal points.

#### 5.3 Best Priority Search Algorithm

In some cases, if we can pre-calculate the distance from each node to the terminal points, we can use this information to get to the destination faster. Similar to Dijkstra algorithm, this algorithm USES a priority queue to save the distance of each node to the terminal points as a reference value, and always selects the node nearest to the terminal points as the node to be traversed next.
5.4 A* Algorithm

Because of the flexibility and diversity of a*, it is widely used in path search. Similar to other graph search algorithms, a* can search a large area of a graph. The a* algorithm combines the features and advantages of dijkstra and search BFS, which can be well used to quickly search the shortest path, and it is also possible to use heuristic functions to guide itself. It is just as fast as searching for BFS in case the obstacle path is not complicated. In the case of rapid search of more complex obstacles, a* algorithm can quickly find a shorter search path similar to dijkstra algorithm. To sum up, the a* algorithm can flexibly find the best path in the application of indoor navigation.

The A* algorithm is quite flexible, combining the advantages of Dijkstra algorithm and BFS algorithm. The A* algorithm calculates the priority of each node using the following function.

\[ f(n) = g(n) + h(n) \]  

\( F (n) \) is the synthetic priority of node n. "When selecting the next traversal node, the algorithm selects the node with the highest synthetic priority. "G (n) is the distance between the node n and the starting point, and is often referred to as the cost. H (n) is called the heuristic function of A* algorithm, that is, the estimated cost at the end of the node n distance.

Add the starting point to the open set

![A* algorithm flow](image)

**Figure 4.** A* algorithm flow

In extreme cases, when the heuristic function h(n) is always 0, the priority of nodes is determined by g(n), and the algorithm is equivalent to Dijkstra algorithm. At the other extreme, if h(n) is much larger than g(n), then h(n) plays a decisive role and becomes the best search algorithm. If h(n) end is less than or equal to the cost of the node to the end point, the A* algorithm guarantees that it can find the shortest path. However, the smaller the value of h(n) is, the more nodes the algorithm will traverse, which results in the slower operation of the algorithm. If h(n) is completely equal to the cost from the node to the end point, then the A* algorithm will find the best path and run fast. This is not possible in all scenarios, however, because when a node does not equal an endpoint, the program cannot predict the cost of that node to the endpoint. If the value of h(n) is greater than the cost of node n to the end
point, the A* algorithm cannot guarantee to find the best solution, but the running time of the algorithm is shortened at this time. The analysis above shows that the accuracy and speed of the algorithm can be adjusted by adjusting the heuristic function. Because of this feature, users can balance speed and accuracy. Because in some cases, we may not need the shortest path, but want to find one as soon as possible. This is where the A* algorithm is more flexible.

6. References

[1] Jian Zhang, Research and implementation of indoor location technology based on iBeacon, [D] Chengdu: Chengdu university of technology, June 8, 2016
[2] Rui Zhang, Research on indoor location algorithm improvement based on iBeacon, [D]. Chengdu: university of electronic science and technology, 2019, 30
[3] XiaoChen Zhou, Research on bluetooth indoor location algorithm based on iBeacon [J] Computer knowledge and technology, 209,15(25):258-259
[4] WenYu Cai , ZhanYe Zhou , Dong Zhang,  Research on indoor location algorithm based on BL4.0 iBeacon technology [J] Journal of hangzhou dianzi university, 2016,3 (65) : 1-5
[5] JianDong Li , WangGen Wan,  Research on optimal path planning algorithm based on crowd density [J] Electronic measurement technology,2020,43(2):38-42
[6] ZhenXing Lu, Research on indoor location system and algorithm based on iBeacon [D] Guangdong: jinan university, 2017, 22