Huawei CloudCampus WLAN Location

Technology White Paper

HUAWEI

Executive Summary

With the wireless communication technology development and data processing capability increase, the location-based service (LBS) has become one of the most promising mobile Internet services. Thanks to its advantages, WLAN location is receiving more and more attention and application. This technology paper describes the implementation and application of WLAN location.

Contents

1 Overview

1.1 Background

Development of wireless communications technologies and improvement in data processing capability make location-based services one of the most promising mobile Internet services. The demand for accurate and fast location-based services becomes more and more stringent in both indoor and outdoor environments. Wireless communications technology is used to locate mobile terminals through measurement and calculation of related parameters. The obtained information facilitates location-based service provisioning, optimizes network management, and improves service quality and network performance.

1.2 Technical Implementation

Huawei WLAN location solution consists of tag location and Wi-Fi terminal location.

Huawei partners with third-party vendors to deliver tag location solutions (including Wi-Fi tags and BLE tags). The third-party vendors provide tags, location engine, and monitoring platform while Huawei provides APs and ACs.

A Wi-Fi terminal location solution (including Wi-Fi terminals and Bluetooth terminals) can be independently delivered by Huawei or provided by Huawei and its partners.

1.3 Customer Benefits

WLAN location technology brings considerable benefits to customers. Compared with other location systems, WLAN location has low costs and applies to various scenarios. It helps locate rogue APs and network faults in a timely manner, improving O&M efficiency. In addition, value-added applications based on WLAN location technologies, such as asset management and security monitoring, provides enterprises with an increased level of security assurance and improved efficiency. Precise advertisement push creates significant business values. Huawei tag and terminal location solutions achieve a location accuracy of 3–5 meters at a movement speed lower than 3 km/h.

- Low deployment costs

WLAN has become one of the most popular hotspot access modes and widely used in shopping malls, office buildings, restaurants, cafes, and parking lots. WLAN location technology uses existing devices on a WLAN and requires no additional devices to offer location services, reducing deployment and O&M costs.

- Wide application

  There are increased requirements on indoor applications of wireless location technologies, such as indoor navigation and asset location. Traditional location systems such as GPS and cellular systems are inapplicable to indoor scenarios because they provide no signals or poor signals indoors. WLAN location applies to both outdoor and indoor scenarios. Different from GPS or cellular system, the Wi-Fi system is widely deployed and Wi-Fi signals are available indoors. This is also one important reason that most indoor location technologies are implemented based on the Wi-Fi system.

- Rich value-added services

  Rich value-added services are developed based on WLAN location technology, which brings customers security, efficiency, and business values. Common applications include personnel tracking and locating, device and asset management, indoor navigation, advertisement push, customer flow analysis, and smart shopping guide.

2 Implementation

Huawei WLAN location solution consists of Wi-Fi tag location, Wi-Fi terminal location, BLE tag location, and Bluetooth terminal location.

2.1 Wi-Fi Tag Location

2.1.1 Components

The Wi-Fi tag location solution is made up of location tags, Wi-Fi network, location engine, and monitoring platform. In actual applications, tag location data can be integrated to an enterprise application platform such as the Enterprise Resource Planning (ERP) platform.

Location Tag

Location tags are attached to targets (such as assets or personnel) that need to be tracked and periodically send radio signals to APs on the 2.4 GHz band. Based on tracked targets, the location tags are classified into asset location tags and personnel location tags. Some tags support two-way communications. An alarm can be generated through a button on the tags. Sending radio signals consumes power of tags. All tags have a battery life, usually four years. (The battery life varies depending on tags and the signal sending interval. A larger sending interval indicates a longer battery life. A four-year battery life corresponds to a signal sending interval of 1 hour.) There are also rechargeable tags, which are not limited by the battery life.

Wi-Fi Network

The Wi-Fi network collects and forwards tag signals.

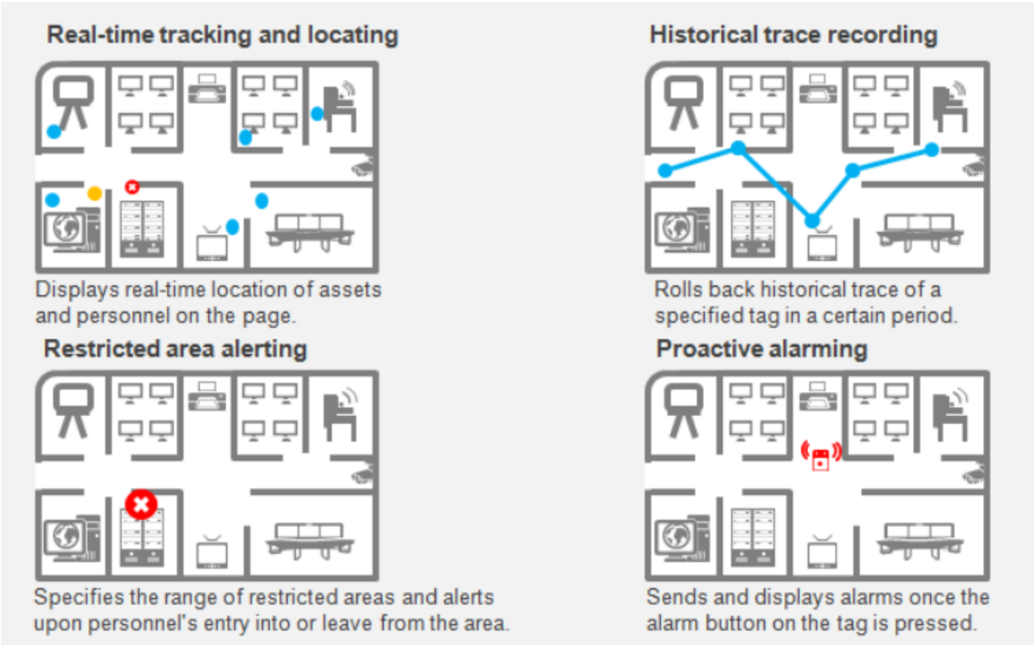
- APs receive location information sent by Wi-Fi tags and forward the information to an AC or a location server.
- The AC forwards the configuration instructions delivered by the location server to the APs. It also functions as a transit station to forward location information sent from the APs to the location server.

Location Server

Physically, a location server works as both a location engine and a monitoring platform. Figure 2-1 shows tag location services.

- The location engine runs the location algorithm to calculate locations of Wi-Fi tags based on the collected location information.
- The monitoring platform displays tag locations on electronic maps, records and queries the historical traces of tags, and makes notifications and alarms based on the specified rules.

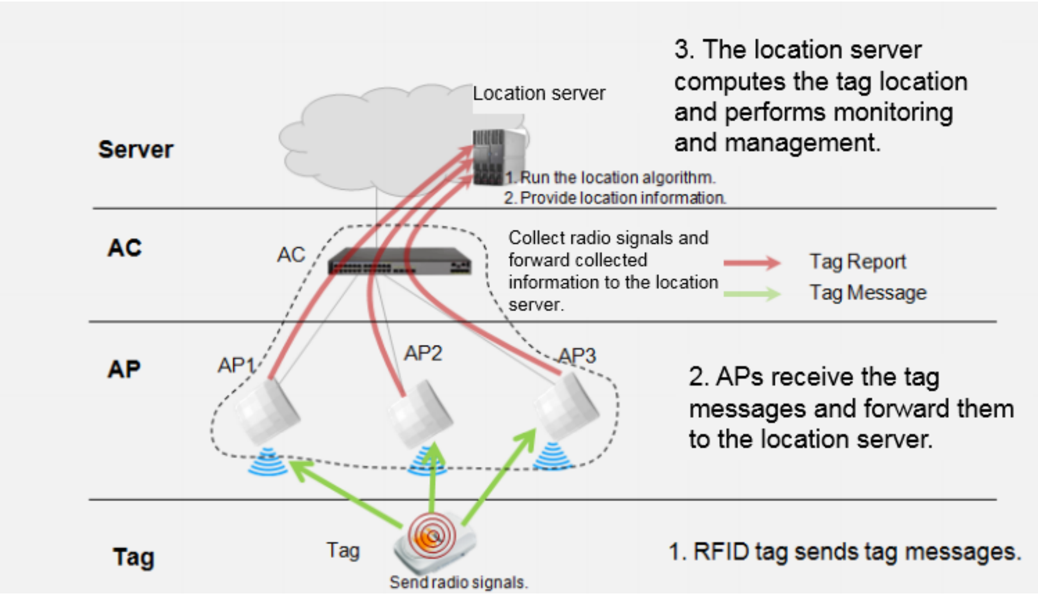
Figure 2-1 Tag location services



2.1.2 Location Principles

The tag location principles will be introduced in terms of the process. Tag message formats vary depending on tag producers and require customized APs for message parsing. Huawei WLAN products can parse frames sent by Ekahau and AeroScout tags, and have passed strict verification and certification tests.

Figure 2-2 Wi-Fi tag location process (assuming that location information passes through an AC)



Step 1 A Wi-Fi tag sends a tag message.

The Wi-Fi tag does not need to connect to the WLAN. It sends 802.11 frames periodically. To ensure that signals sent by the tag can be listened on by more APs, the RFID tag sends tag messages simultaneously on all channels. Tag messages may have different formats, but all tag messages contain information required by the location server for tag location.

Step 2 The AP receives the tag message and forwards it to the location server.

After receiving the tag message, the AP records the received signal strength indicator (RSSI), MAC address, and channel. The RSSI is the most important information and key data used by the location server to determine the distance between the tag and AP. To ensure the accuracy of the RSSI, the AP needs to filter out tag messages received from adjacent channels. For example, if an AP works on channel 1, it may receive frames sent by the tag on channel 1. Since the AP and tag work on different channels, the RSSI of the received frame is low. The location server may incorrectly consider that the tag is far from the AP. Therefore, tag messages received from adjacent channels must be filtered out.

The AP encapsulates all tag messages into a UDP packet (tag report) and sends the UDP packet to the location server directly or through the AC. The report mode and location information required differ slightly according to location servers of different vendors. For example, the Ekahau location server requires APs to report tag messages in real time, but the AeroScout location server allows APs to periodically report multiple tag messages at one time.

The destination IP address and port number in a tag report are configured on the AC. If the destination address is configured as the location server, the AP directly sends the tag report to the location server. If the destination address is configured as the AC, the AP sends the tag report to the AC, and the AC forwards the tag report to the location server. This mode applies to scenarios where the AP cannot directly communicate with the location server.

Step 3 The location server calculates the tag location.

To accurately determine the location of the RFID tag, the location server needs to receive RFID tag information from at least three APs. After receiving the tag report from the APs, the location server uses a built-in location algorithm to calculate the tag location based on the imported map, marked AP locations, and information carried in the tag report such as the RSSI and radio mode. The location server then sends the location information to the graphical interface of the third-party device for presentation.

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2.2 Wi-Fi Terminal Location

The WLAN terminal location solution requires no Wi-Fi tags and can locate regular Wi-Fi terminals.

2.2.1 Components

The Wi-Fi terminal location solution is logically composed of Wi-Fi terminals, a Wi-Fi network, a location engine, and a monitoring/application platform. Huawei Wi-Fi terminal location solution uses eSight or a third-party NMS as the location engine and server.

Wi-Fi Terminal

Wi-Fi terminals send radio signals.

Wi-Fi Network

- APs collect radio signals. The AP collects RSSI information of Wi-Fi terminals, and reports the information to the location server to locate Wi-Fi terminals. RSSI information must contain the AP ID, STA ID, RSSI, and channel. The APs can send the collected location information directly to the location server or to an AC first. The AC will filter the information before sending it to the location server.
- If the APs report the RSSI information to the AC first, the AC filters the information before sending it to the location server.

Location Server

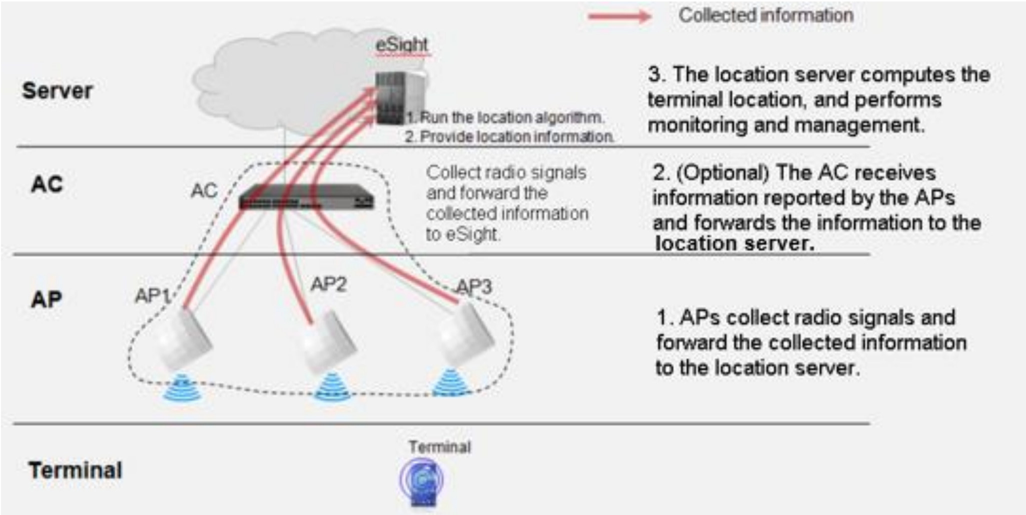
The location server typically has a location engine and monitoring/application platform integrated. Huawei's solution uses eSight as the location server or a third-party location server.

- The location engine computes the signal propagation model according to locations of APs and obstacles, and calculates locations of Wi-Fi terminals based on the RSSI information reported by APs or the AC.
- The monitoring/application platform displays Wi-Fi terminal locations on electronic maps, records and queries the historical traces of terminals, and makes notifications and alarms based on the specified rules.

2.2.2 Location Principles

Similar to APs in the Wi-Fi tag location solution, APs in the terminal location solution need to collect radio signal information and send the information to the location server. The location server then calculates the terminal location using the location algorithm.

Figure 2-3 Wi-Fi terminal location process (assuming that location information passes through an AC)



Step 2 An AP collects RSSI information about radio signals and forwards the information to the location server.

1. The AP periodically switches channels to collect frames sent from terminals in the surrounding environment on each channel and records location information in the received frames, including the RSSI, timestamp, rate, and channel. The RSSI is the most important information and key data used by the location server to determine the distance between the terminal and AP.
2. The AP encapsulates the collected radio signal information and reports the data to the location server in either of the following modes:
   - The AP reports the collected data to the AC, which then reports the data to the location server.

     If the network between the AP and location server is unreachable, the AP can send the data to the AC first. The AC filters the data, selects location information about Wi-Fi terminals and APs out of the local network, and reports the data to the location server.
   - The AP directly reports the data to the location server.

     If the network between the AP and the location server is reachable, and the AC is not required to identify APs, the AP can directly send data to the location server. This prevents the impact on WLAN services because the AC does not need to process location data. In this mode, the AP reports packets to the location server only through UDP.

Step 3 (Optional) The AC receives information reported by APs and forwards the information to the location server. The AC can report packets to the location server using UDP or HTTP.

When the AP reports data to the AC first, the AC processes the data as follows:

1. The AC checks whether the data reported by the APs is location data based on the destination port number. If not, the AC processes data in other ways.
2. When the AC receives location data, it checks the type of devices that send the data. If the data is sent from an access terminal, the AC reports the data to the location server. If the data is sent from an AP, the AC checks whether the AP is on the local network. If so, the AC discards the data and sends location data of only APs out of the local network to the location server.

Step 4 The location server calculates the terminal location.

The location server typically computes the terminal location in the following phases:

- **Offline phase**: The location server divides the whole network into multiple equal area grids and derives the radio signal propagation model according to onsite environment characteristics (characteristics of indoor/outdoor environments and obstacles). In combination with AP locations imported to the location server, the location server calculates the RSSI of a STA in a grid to each AP and stores the information in the database.
- **Online phase**: APs (at least three) report the received terminal location information to the location server. The location server compares the RSSI information received by each AP with the information in the database to obtain the terminal location.

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2.3 BLE Tag Location

2.3.1 Components

The BLE tag location solution is made up of location tags, a Wi-Fi network (APs with built-in Bluetooth modules), a location engine, and a monitoring/application platform. In actual applications, tag location data can be integrated to an enterprise application platform such as the ERP platform.

BLE Tag

BLE tags are attached to targets (such as assets or personnel) that need to be tracked and periodically broadcast BLE frames. Tags are classified into asset location tags and personnel location tags. Sending signals consumes power of tags. All tags have a battery life, usually three to five years. (The battery life varies depending on tags and the signal sending interval. A larger sending interval indicates a longer battery life.)

Wi-Fi Network

The Wi-Fi network collects and forwards BLE broadcast frames from tags.

- Built-in Bluetooth modules of APs receive BLE broadcast frames sent by BLE tags and forward the information to an AC or a location server.
- The AC functions as a transit station to forward location information sent from the APs to the location server.

Location Server

Physically, a location server works as both a location engine and a monitoring/application platform.

- The location engine runs the location algorithm to calculate locations of BLE tags based on the collected location information.
- The monitoring/application platform displays tag locations on electronic maps, records and queries the historical traces of tags, and makes notifications and alarms based on the specified rules.

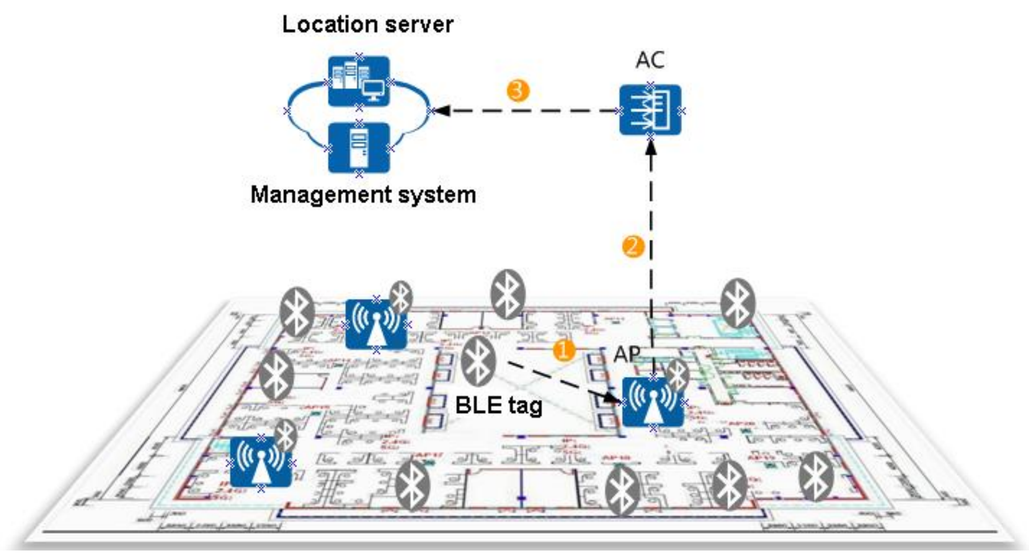
2.3.2 Location Principles

The location algorithm is not provided by the WLAN, and its details are not described here. BLE broadcast frames sent by BLE tags must meet specified requirement so that the frames can be correctly identified and processed by the WLAN. Huawei WLAN supports the following types of BLE broadcast frames:

- iBeacon broadcast frames
- Huawei-defined BLE broadcast frames. For details about the interface definition, see the *Huawei Bluetooth Interface Definition Specifications 1.1*.
- Standard BLE broadcast frames, which are applicable to transparent data transmission scenarios. The WLAN does not need to parse the broadcast frame content. Therefore, the WLAN cannot support power monitoring or disconnection alarms.

Figure 2-4 shows the implementation process for locating BLE tags.

Figure 2-4 BLE tag location process (assuming that location information passes through an AC)



Step 1 A BLE tag sends BLE broadcast frames.

A BLE tag sends BLE broadcast frames periodically. To ensure that the frames sent by the tag can be scanned by more APs, the BLE tag sends the BLE broadcast frames on all broadcast channels.

Step 2 An AP receives BLE broadcast frames, processes the frames, and then forwards them to the location server.

After receiving the BLE broadcast frames, the AP records the RSSI and MAC address of each frame. The RSSI is the most important information and key data used by the location server to determine the distance between the tag and AP.

The AP sends all the received BLE tag information to the location server directly or through the AC. Currently, Huawei WLAN supports the following reporting interfaces:

- Northbound reporting interface defined by Huawei. For details, see the *Huawei Bluetooth Interface Definition Specifications 1.1*.
- HTTP interface defined by bluepath, through which location data is reported to a bluepath server.

The destination IP address and port number in a tag report are configured on the AC. If the destination address is configured as the location server, the AP directly sends the tag report to the location server. If the destination address is configured as the AC, the AP sends the tag report to the AC, and the AC forwards the tag report to the location server. This mode applies to scenarios where the AP cannot directly communicate with the location server.

Step 3 The location server calculates the tag location.

After receiving the tag report from the APs, the location server uses a built-in location algorithm to calculate the BLE tag location or area based on the imported map, marked AP locations, and information carried in the tag report such as the RSSI. The location server then sends the location information to the graphical interface of the third-party device for presentation.

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2.4 Bluetooth Terminal Location

Bluetooth terminal location can directly locate common Bluetooth terminals, such as mobile phones or tablets, without the help of BLE tags.

2.4.1 Components

The Bluetooth terminal location solution is logically composed of Bluetooth terminals, a Wi-Fi network, a location engine, and a monitoring/application platform.

Bluetooth Terminal + App

The app on a Bluetooth terminal triggers scanning of BLE broadcast frames sent by built-in Bluetooth module of APs or Bluetooth beacons, and obtains the frame content and RSSI. Common Bluetooth terminals include mobile phones and tablets.

Wi-Fi Network

The built-in Bluetooth module of an AP periodically sends iBeacon broadcast frames. The broadcast interval, broadcast content, and transmit power are configurable.

The distance between APs is about 15 m, and the Bluetooth coverage is generally less than 10 m. Therefore, an independent Bluetooth beacon can be deployed to supplement signal coverage. Bluetooth beacons are provided and configured by third-party vendors. Additionally, if Bluetooth beacons support the scan response BLE broadcast frame interface defined by Huawei, APs can manage power on the Bluetooth beacons by periodically detecting the power level and reporting low power alarms.

Monitoring/Application Platform

The monitoring/application platform provides enterprise application capabilities, and can obtain map information and terminal location information from the location server for presentation.

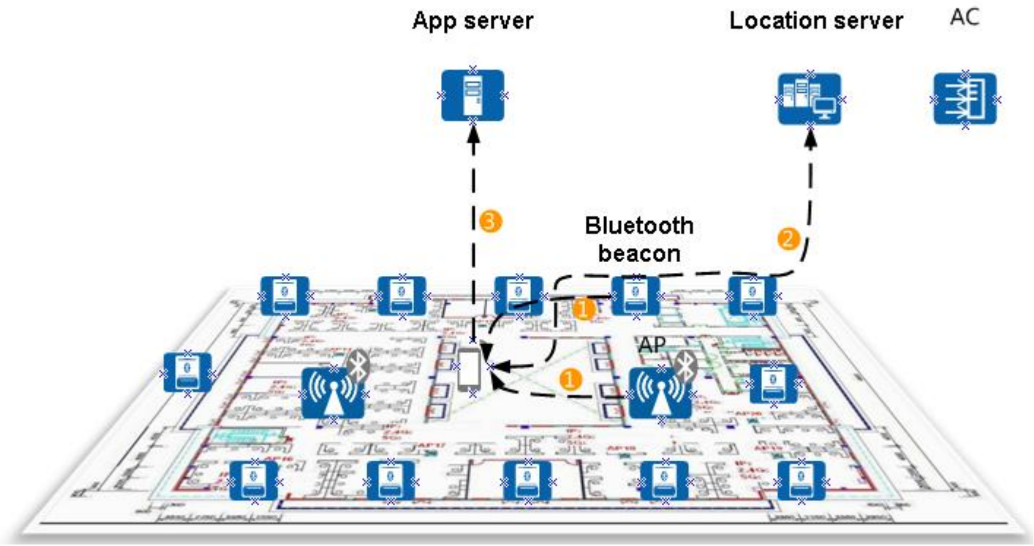
2.4.2 Location Principles

The location engine and monitoring software are integrated on the location server, similar to those in the BLE tag location solution. Huawei terminal location solution uses eSight NMS as the location server.

Bluetooth terminal location supports terminal-side location and network-side location. The network-side location mechanism is the same as the Bluetooth tag location mechanism and is not mentioned here. The following describes only terminal-side Bluetooth location.

The built-in Bluetooth module of an AP periodically sends iBeacon broadcast frames. Bluetooth terminals scan signals and trigger location calculation.

Figure 2-5 Bluetooth terminal location process (assuming that location information passes through an AC)



Step 1 The built-in Bluetooth module of an AP or a Bluetooth beacon periodically broadcasts iBeacon frames.

The broadcast interval, broadcast content, and transmit power of the built-in Bluetooth module are configurable.

Bluetooth beacons are configured by third-party vendors. If Bluetooth beacons support the scan response BLE broadcast frame interface defined by Huawei, APs can manage power on the Bluetooth beacons by periodically detecting the power level and reporting low power alarms.

Step 2 A Bluetooth terminal scans iBeacon broadcast frames, obtains maps information from the location server based on the location SDK, and calculates its own location. Alternatively, the terminal can report scanned data to a location server, which then calculates the terminal location.

Step 3 The location server calculates the terminal location.

The location server typically provides a location algorithm SDK, which is integrated on the app to calculate a Bluetooth terminal location. The location server also supports location calculation based on information reported by the Bluetooth terminal, and is capable of editing and planning maps.

Step 4 The app server provides enterprise application services.

The app on a terminal interacts with the app server based on the location information to trigger specific application services, such as pushing preferences and discount information.

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3 Application Scenario

WLAN location is widely applicable to many scenarios, including location-based navigation, value-added service analysis based on historical location data, and asset and personnel tracking.

3.1 Location-based Navigation

3.1.1 Core Requirements

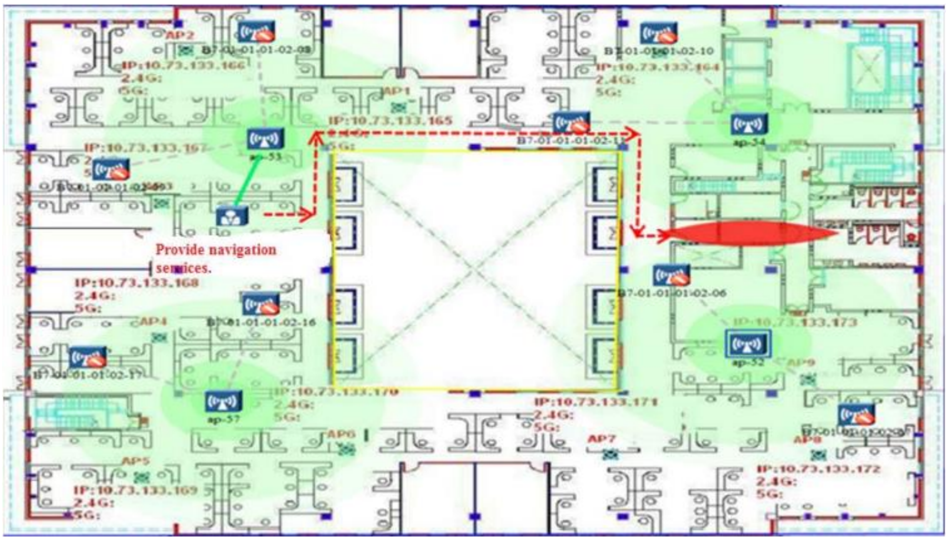
Wireless location provides following navigation services:

- In a shopping mall, consumers can use the wireless location system to obtain location information about surrounding stores and select their preferred stores for shopping.
- Shop vendors can accurately push advertisements based on consumer locations.
- In a scenic area, tourists can use the wireless location system to obtain location information about surrounding tourist attractions and go to visit their preferred scenic spots.
- In a large parking lot, car drivers can quickly find their parking spaces based on their real-time locations.

3.1.2 Solution

The wireless location system provides the terminal location service. For Wi-Fi terminals, a third-party system obtains user locations through an API and offers user navigation services accordingly. However, for Bluetooth terminals, the terminal-side location solution is more commonly used.

Figure 3-1 Location-based navigation scenario



3.2 Value-Added Service Analysis Based on User's Historical Locations

3.2.1 Core Requirements

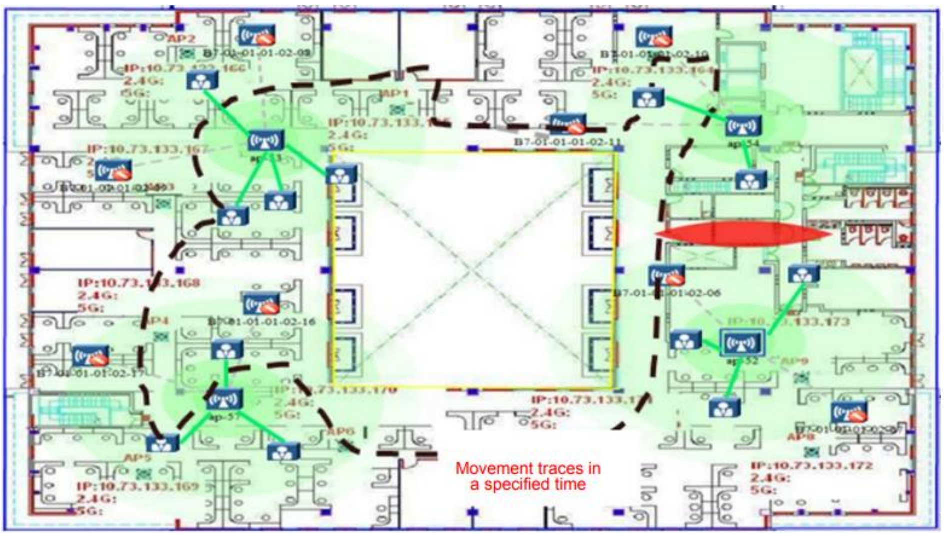
Value-added services that are developed based on user's historical locations involve the following:

- The shopping mall analyzes the time duration when consumers stay in a store based on historical location data, and offers them shopping guide based on the analysis results.
- The shopping mall can analyze consumer traffic of different stores based on the consumers' stay time in each store and charges for rental based on the statistical analysis.

3.2.2 Solution

The wireless location system can store users' historical location data and offer a third-party API to obtain historical movement traces of users for further analysis.

Figure 3-2 Value-added service scenario



3.3 Asset and Personnel Tracking

3.3.1 Core Requirements

Healthcare, oil, gas, mining, and education industries need to monitor assets and personnel to ensure their safety. Wireless location technology provides enterprises with an increase level of security assurance and improved efficiency.

Figure 3-3 Asset and personnel tracking scenario

3.3.2 Solution

The Wi-Fi tag or BLE tag location solution is applicable to this scenario.

3.4 Smart Shopping Guide

3.4.1 Core Requirements

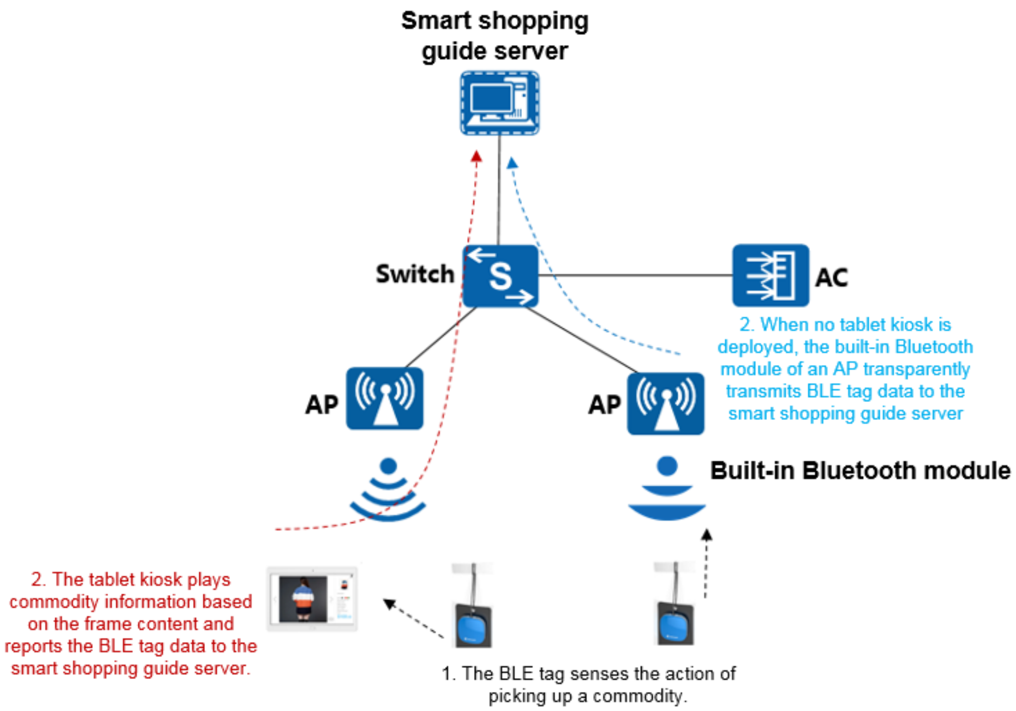
Smart shopping guide can provide high-tech shopping experience for customers of enterprises such as shopping malls and stores, improve the market image and brand value of enterprises, and promote their sales and benefits.

3.4.2 Solution

The specific application scenarios are as follows:

- Customers pick up commodities.
- With a built-in gravity sensor, BLE tags can sense the action of picking up commodities and automatically send BLE broadcast frames.
- After scanning the frames, tablet kiosks play commodity information based on the frame content and report BLE tag data to the smart shopping guide server through Wi-Fi for Big Data analytics.
- If no tablet kiosk is deployed, the built-in Bluetooth module of an AP can scan and report broadcast frame information to the smart shopping guide server for commercial Big Data analysis.

Figure 3-4 Smart shopping guide application



A Acronyms and Abbreviations

A

AP	Access Point
AC	Access Controller

F

FFT	Fast Fourier Transformation

R

RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indicator

G

GIS	Geographical Information System

S

STA	Station

W

WLAN	Wireless Local Area Network

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