Location-Aware Interaction and Indoor Navigation: Using Beacon Technology to Aid Visitors

ABSTRACT

Different from a Global Positioning System (GPS) that provides outdoor localization services, Bluetooth Low Energy (BLE) beaconing is a current emerging technology that provides a pragmatic solution for low cost, lightweight, scalable, relatively accurate indoor localization services. The beacon technology uses pervasive small wireless sensor beacons that can pinpoint the location/proximity inside a building and transmit signals to mobile devices. My project investigates applying the beacon technology to help new visitors identify their location inside a building and receive location-aware information and notifications instantly by interacting with their mobile devices. My approach includes developing a mobile application with beacon scanning function to demonstrate the usage simulation of beacons in an airport to allow passengers to receive critical travel information when they approach or enter specific physical locations. I have also conducted experiments with this application to study the accuracy and responsiveness of using the beacons to determine a visitor's location and to trigger interaction with him/her of location-aware information. Through beacon technology, visitors can be provided personalized, real-time, location-aware information and even indoor navigation cues to ease their way around their physical surroundings. This capability has the potential to be very helpful to those encountering an unfamiliar building, or the visually impaired who may need assistance with navigation. Moreover, this work may have widespread adoption to improve user experiences in other areas such as retail outlets, museum tours and hospitals. Future work comprises more advanced location calculation algorithms and visual indoor navigation with the beacon technology.

PROBLEM STATEMENT

Indoor localization and location-aware services

The demand for Indoor localization services has been increased considering the inconveniences and problems that many people may face when they are entering an unfamiliar building such as an airport, a hospital, a conference convention and any other indoor environments where outdoor positioning systems like Global Positioning System (GPS) is unable to work effectively. Indoor localization systems are not only critical to help visitors find their way through a large building but also enable business providers to enhance customers' experiences by delivering location-aware services such as location-specific information, Ads, tracking and even billing.

Is beacon technology the best choice?

Unlike Global Positioning System (GPS) that has gained much success, indoor localization systems are still at an initial stage due to the dependency on network infrastructures , high cost, complexity in configuration, deployment and maintenance. To overcome these limitations, the Bluetooth Low Energy (BLE) beaconing is an emerging technology that

- uses wireless sensor beacons that transmit signals to mobile devices;
- allows mobile applications to listen for signals from beacons;
- pinpoint the relative location (proximity) inside a building;
- delivers content and experiences to users triggered by their location

Compared to other potential indoor localization technologies such as Google's Tango project, the beacon technology has been integrated into Apple's products named ***iBeacon*** and has recently gained a lot of attention mainly because the beacons are low cost, have low energy consumption and are easy to deploy. Will the beacon technology be the right choice to provide low cost, lightweight, scalable, accurate indoor localization services for aiding visitors? This project aims to explore these possibilities.

OBJECTIVES

The purpose of my project is to enable users to interact effectively with physical surroundings through beacon technologies and to facilitate instant delivery of location-specific information and experiences to users.

The objectives include:

1) Building a mobile app for the usage simulation of beacons in an airport;
2) Helping users gain a better understanding of their locations with the app;
3) Delivering location-aware Information/services to users on the app;
4) Determining if it is low cost and easy to build a beacon localization system

USING BEACONS

My approach includes developing a mobile application with beacon scanning function to demonstrate the usage simulation of beacons in an airport. Three beacons are used in this project. A beacon transmits the following information via BLE:

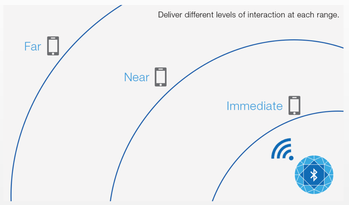
- **UUID:** to distinguish your beacons from other beacons;
- **Major:** to further specify beacons in a group;
- **Minor:** to allow further subdivision of beacons.

Using the above information, a mobile device could identify when it has entered or left a specific region defined by a beacon.

Apple's Core Location APIs: RSSI and Proximity

Apple's core location APIs are used to detect beacons' signal and determine the mobile device's proximity to the beacons.

The strength of the signal (**RSSI**, or **R**eceived **S**ignal **S**trength **I**ndication) is used to determine both proximity to the beacon, as well as the accuracy of its estimation of proximity. Based on the strength of the signal, there are four proximity states can be identified: **Immediate**, **Near**, **Far**, **Unknown**

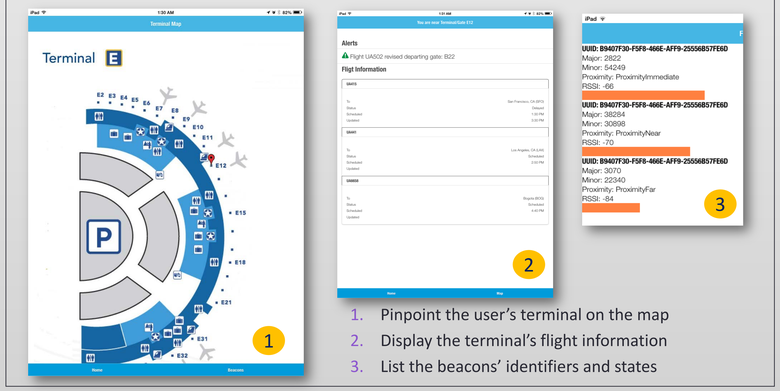


https://passkit.com/how-ibeacon-works/

IEASYAIRPORT: AN OVERVIEW

The mobile app **IEasyAirport** is developed to simulate the usage of beacons in an airport. It has these functions:

- Listening for beacon's signal and identifying beacons' UUID, major and minor;
- Collecting beacons' RSSI and proximity and display them visually;
- Determining the closest beacon and pinpoint the corresponding terminal on a map;
- Displaying flight info, gate change , etc. based on the pinpointed terminal.



1. Pinpoint the user's terminal on the map
2. Display the terminal's flight information
3. List the beacons' identifiers and states

DEVELOPMENT: CORDOVA FRAMEWORK

- The **IEasyAirport** app is an iOS app that can run on an iOS device. It uses Apache Cordova, a platform for building native mobile applications using HTML, CSS and JavaScript. (http://cordova.apache.org/). The lines of code (LOC) for beacon functions is less than 30 (see below), which is a pretty small program.
- The Cordova iBeacon Plugin embeds Apple's Core Location APIs to provide JavaScript-like APIs to detect beacons. The code of detecting beacons is a revision from a sample project (http://evothings.com/doc/examples/ibeacon-scan.html)

```
// Start monitoring and ranging beacons.
for (var i = 0; i < beaconRegions.length; i++) {
    var beacon = beaconRegions[i];
    cordova.plugins.locationManager.startMonitoringForRegion(beacon)
    .fail(console.error)
    .done();
    cordova.plugins.locationManager.startRangingBeaconsInRegion(beacon)
    .fail(console.error)
    .done();
}
```

The lines of code for beacon functions

- ✓ *Specifying beacons: 3*
- ✓ *Detecting beacons: 5*
- ✓ *Determining the closest beacon: 17*

```
// determine which beacon is cloest
$.each(beacons, function(key, beacon)
{
        // Only show beacons that are updated during the last 60 seconds.
    if (beacon.timeStamp + 60000 > timeNow)
    {
        // Map the RSSI value to a width in percent for the indicator.
        var rssiWidth = 1; // Used when RSSI is zero or greater.
        if (beacon.rssi < -100) {
            rssiWidth = 100;
        }
        else if (beacon.rssi < 0) {
            rssiWidth = 100 + beacon.rssi;
        }
        if(rssiWidth > lastRssiWidth){
            lastRssiWidth = rssiWidth;
            closestBeaconMajor = beacon.major;
        }
    }
});
```

EXPERIMENTS AND DATA

The experiments were conducted to examine if the **iEasyAirport** app detected beacons and pinpointed user's location with acceptable accuracy and within acceptable response time. The procedures include:

- Deployed three beacons to different locations to represent 3 gates
- Walked to each beacon and see if the app pinpoints the closes t gate
- Collected the data in regards to responsiveness and accuracy

	Beacon 1		Beacon 2		Beacon 3	
Tries	Correctly detected?	Response time (ms)	Correctly detected?	Response time (ms)	Correctly detected?	Response time (ms)
1	Y	<1	Y	<1	Y	<1
2	Y	<1	Y	2075	Y	<1
3	Y	1079	Y	2042	Y	<1
4	Y	<1	Y	1039	Y	<1
5	Y	2057	Y	<1	Y	<1

The above results showed the accuracy rate is 100%, and the app detected the user's location usually within 3 seconds. In addition, my approach does not need any particular tools to deploy beacons, they could be just attached to the walls.

CONCLUSIONS AND FUTURE WORK

To conclude, the beacon technology can reliably identify a user's relatively accurate location (proximity instead exact position) and trigger location-aware info instantly on a mobile device. The effort to create a beacon-based solution is low in writing a beacon detection app and deploying the beacons.

Moreover, visitors can be provided personalized location-aware information and indoor navigation cues in multiple language or by sound. This capability has the potential to be very helpful to those speaking a foreign language, or the visually impaired who may need assistance with navigation.

Lastly, this work may have widespread adoption to improve user experiences in other areas such as retail outlets, museum tours and hospitals.

Future work comprises more advanced location calculation algorithms and visual indoor navigation with the beacon technology, including multiple floors routing.