

Delving Deep into the World of Beacons Comparative Study of Available Platforms for Beacons

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Abstract - Beacons are tiny Bluetooth based devices powered by Bluetooth Smart (Bluetooth 4.0) or BLE. They have a huge and varied field and application ranging from location based services to smart shopping using mobile wallets. The four major platforms currently available are iBeacon by Apple, Eddystone by Google, AltBeacon by Radius Networks(Creative Commons) and GeoBeacon by Tecno-World. Beacons do not monitor nearby mobile devices or even control things, they simply transmit their signal continuously. iBeacon was the first to be introduced, later AltBeacon then eddystone followed and recently GeoBeacon came into the picture. Although each of them have their similarities, they are all unique in application. iBeacon although a little lacking in a few aspects compared to its counterparts is still in the forefront of the beacon world. Most implementations so far in any application have been using iBeacons as they are very reliable and extremely smooth in operation. Eddystone, the latest platform is an upgrade to the functionality of the beacons. It introduced three frame types viz UID, URL and TLM. UID is a common frame for all platforms. URL lets beacons transmit the URL link of a website which will guide the user directly to the website. TLM or telemetry is another phenomenal achievement that lets the device transmit data like battery level or temperature. This certainly increases the application variety for beacons. AltBeacon is an open source as well as interoperable platform. AltBeacon first introduced the android beacon library and is backwards compatible with iBeacon as well. AltBeacon also provides more space for data as compared to iBeacon. This makes it the most comfortable platform to work with and also the only proprietary free platform. GeoBeacon is a protocol specification that defines a message format for proximity beacon advertisements. GeoBeacon proximity beacon advertisements are transmitted by devices for the purpose of signaling their proximity to nearby receivers. The contents of the emitted message contain information that the receiving device can use to compute its relative distance to the beacon, to check the battery status, to get Geo coordinates and to get user defined data. These are all simple to operate and make working with beacons fun.

Key Words: Beacon, Bluetooth Smart, BLE, iBeacon, Eddystone, UID, URL, TLM, AltBeacon, GeoBeacon

1. INTRODUCTION

IoT has developed into a beam engine of Brobdingnagian proportions and Beacons are known as genius hidden compartment of this beam engine. The Beacons are small objects transmitting location information to the bluetooth enabled smartphones and other devices powered by Bluetooth Smart (BLE). The Beacons technology promises several services such as mobile wallet, mobile couponing, and location-based services.

The retail space is the first to envision a future for this interesting technology ranging from in-store analytics to proximity marketing, indoor navigation and contactless payments. Imagine a customer who is looking at a new TV and he/she instantly gets a text with a 25 percent discount coupon for that same TV and an online payment option using an online account. Retailers are also looking at using beacons to unlock doors for you, or even prepare your favorite drink when you walk into the shop.

Applications go beyond retail or location based marketing. For instance, SK Telecom and Seoul National University Bundang Hospital are using Bluetooth Smart beacons to provide round-the-clock patient information and navigation to its 6,000 daily patients. Analysts estimate beacons, acting as hubs, will be deployed all over airports and transit stations to easily send out notifications on departures, delays, passenger assignments, etc. There is also possibility of Bluetooth beacons being deployed in the smart home.[1]

This paper focuses on various platforms available to program beacons as per applications. This work will be useful to solve all kinds of developer's dilemma in terms of selecting a platform amongst four major ones.

2. Beacons : Demystified

Bluetooth Beacon is a small electronic device that typically runs on small batteries. They were first mentioned in Apple developers conference of 2013. Since then beacon brands have multiplied and there are a dozen or so at present. Beacons are available in all sorts of sizes and shapes. The sole purpose of a beacon is to broadcast its ID number over and over. It doesn't listen to anything or gather information on other devices nearby and does not even connect to the Internet to report anything. It simply emits Bluetooth signals that carry little packets having numbers. These ID's or

numbers can be picked up by any bluetooth enabled mobile devices within range of the signal. Unless the devices have Bluetooth enabled and an app that cares for beacons the signals will go unnoticed. The key thing to remember is the beacon yammers on and on about itself and does nothing else. Beacons don't spy on nearby phones. They don't control things. They simply broadcast their packet just like lighthouse shines it's light for ships passing by. The lighthouse doesn't look for ships to light up, simply shines it's light around and around all day everyday. It's the job of ships passing by to react to the light if need be.

3. iBeacon : Apple the forerunner

Introduced in iOS 7, iBeacon is an exciting technology enabling new location awareness possibilities for apps. Leveraging Bluetooth Low Energy (BLE), a device with iBeacon technology can be used to establish a region around an object. This allows an iOS device to determine when it has entered or left the region, along with an estimation of proximity to a beacon . There are both hardware and software components to consider when using iBeacon technology. iBeacon technology helps ensure a highly effective deployment leading to an outstanding user experience.[2]

3.1 DataSpec

iBeacons broadcast four pieces of information:

- 1.A UUID that identifies the beacon.
- 2.A Major number identifying a subset of beacons within a large group.
- 3.A Minor number identifying a specific beacon.
- 4.A TX power level in 2's compliment, indicating the signal strength one meter from the device. This number must be calibrated for each device by the user or manufacturer.

A scanning application reads the UUID, major number and minor number and references them against a database to get information about the beacon; the beacon itself carries no descriptive information - it requires this external database to be useful. The TX power field is used with the measured signal strength to determine how far away the beacon is from the smart phone. Please note that TxPower must be calibrated on a beacon-by-beacon basis by the user to be accurate.

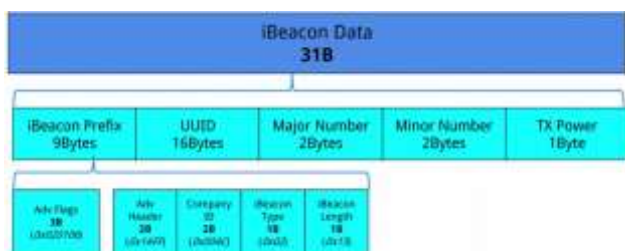


Fig. 1. iBeacon protocol format[3]

3.2 Protocol

An iBeacon advertisement provides the following information via Bluetooth Low Energy:

Table 1.

Field	Size	Description
UUID	16 bytes	Application developers should define a UUID specific to their app and deployment use case.
Major	2 bytes	Further specifies a specific iBeacon and use case. For example, this could define a sub-region within a larger region defined by the UUID.
Minor	2 bytes	Allows further subdivision of region or use case, specified by the application developer.

The UUID, major and minor values provide the identifying information for the iBeacon. Generally speaking, this information is hierarchical in nature with the major and minor fields allowing for subdivision of the identity established by the UUID. UUIDs can be generated by using the uuidgen command line utility in OS X, or programmatically using the NSUUID Foundation class. The following table shows examples of how these values may be used for a nationwide retail store. The UUID is shared by all locations. This allows an iOS device to use a single identifier to recognize any of the stores with a single region. Each specific store, San Francisco, Paris, and London, is then assigned a unique major value, allowing a device to identify which specific store it is in. Within each individual store, departments are given separate minor values, although these are the same across stores to make it easier for an app on a device to readily identify departments.

The iBeacon Prefix contains the hex data : 0x0201061AFF004C0215. This breaks down as follows:

1. 0x020106 defines the advertising packet as BLE General Discoverable and BR/EDR high-speed incompatible. Effectively it says this is only broadcasting, not connecting.
2. 0x1AFF says the following data is 26 bytes long and is Manufacturer Specific Data.
3. 0x004C is Apple's Bluetooth Sig ID and is the part of this spec that makes it Apple-dependent.
4. 0x02 is a secondary ID that denotes a proximity beacon, which is used by all iBeacons.
5. 0x15 defines the remaining length to be 21 bytes (16+2+2+1).

The remaining fields are rather self explanatory. The proximity UUID is a standard 16byte/128bit BLE UUID and is typically unique to a company. The major and minor numbers are used to denote assets within that UUID; common uses are major numbers being stores (so 65,536 stores possible) with

minor numbers being individual tags within the stores (again 65,536 possible tags per store).

3.3 Requirement

To use iBeacon, you need iOS 7 or later, Bluetooth turned on, and a compatible iOS device:

1. iPhone 4s or later
2. iPad (3rd generation) or later
3. iPad mini or later
4. iPod touch (5th generation) or later.

3.4 Applications

With an iBeacon network, any brand, retailer, app, or platform will be able to understand exactly where a customer is in the brick and mortar environment. This provides an opportunity to send customers highly contextual, hyper-local, meaningful messages and advertisements on their smartphones. The typical scenario looks like this. A consumer carrying a smartphone walks into a store. Apps installed on a consumer's smartphone listen for iBeacons. When an app hears an iBeacon, it communicates the relevant data (UUID, Major, Minor, Tx) to its server, which then triggers an action. This could be something as simple as a push message ["Welcome to Target! Check out Doritos on Aisle 3!"], and could include other things like targeted advertisements, special offers, and helpful reminders ["You're out of Milk!"]. Other potential applications include mobile payments and shopper analytics and implementation outside of retail, at airports, concert venues, theme parks, and more. The potential is limitless.

4. Eddystone : Pioneered by Google

Google has introduced an open format for Bluetooth Low Energy (BLE) beacons that is designed to address the shortcomings of existing beacon services and is compatible with both Android and iOS devices. Eddystone is robust and extensible: It supports multiple frame types for different use cases, and it supports versioning to make introducing new functionality easier. It's cross-platform, capable of supporting Android, iOS or any platform that supports BLE beacons. And it's available on GitHub under the open-source Apache v2.0 license, for everyone to use and help improve. Eddystone offers security through a feature called Ephemeral Identifiers (EIDs), beacon IDs that change frequently, allowing only authorised clients to decode them. Developers can also attach cloud-based data to beacons, with the information being looked up and passed to their app by the Eddystone service whenever a relevant beacon comes into range.[5]

4.1 Data Spec

The main data format of Eddystone consists of the following three components.

1. Eddystone Universally Unique Identifier (UID):
2. Namespace: A 10 byte field
3. Instance id: A byte field

Having 128 bit value, UID / UUID uniquely recognizes every particular beacon across the globe thereby enabling an application to listen and perform.

The specific type of Eddystone frame is encoded in the high-order four bits of the first octet in the Service Data associated with the Service UUID. Permissible values are shown in table below.

Permissible values for Eddystone beacons[6]

Frame Type	High-Order 4 bits	Byte Value
UID	0000	0x00
URL	0001	0x10
TLM	0010	0x20
EID	0011	0x30
RESERVED	0100	0x40

4.2 Protocol

Eddystone-UID contains an identifier of a beacon. An app installed on the phone can use the identifier to trigger desired action, just like with iBeacon. Whereas the iBeacon identifier is composed of three parts: UUID, major number and minor number, and is 20 bytes long, Eddystone-UID is 16 bytes long and split into two parts:

1. Namespace (10 bytes), similar in purpose to iBeacon's UUID. In iBeacon, you'd usually assign a unique UUID to all of your beacons to easily filter them out from other people's beacons. In Eddystone-UID, you can do the same with the namespace. Estimote Beacons broadcasting the Eddystone-UID packet have a default namespace set to : EDD1EBEAC04E5DEFA017. For a custom namespace, the Eddystone specification recommends taking the first 10 bytes of an SHA-1 hash of your domain name.
2. Instance (6 bytes), similar in purpose to iBeacon's major and minor numbers, i.e., to differentiate between your individual beacons. With Estimote Beacons broadcasting Eddystone-UID, instance is represented as a string up to 12 characters long (e.g., 0BDB87539B67).

Eddystone-URL packet contains a single field: URL. The size of the field depends on the length of the URL. The promise and purpose of the Eddystone-URL packet ties directly into the concept of *Physical Web*. Whereas with iBeacon or Eddystone-UID there's a need for an app to take the beacon's identifier and translate it into certain actions, with

Eddystone-URL the data is encoded directly in the beacon's advertising packet. This means that the user can access content—usually in form of a website—without having the appropriate app installed.

The URL could be a regular web page providing relevant information—e.g., a beacon next to a movie poster could broadcast a link to a YouTube trailer. It also could be a dynamic web application, with contextual parameters embedded in the e.g. http://my-restaurant.com/check-in?restaurant_id=6523.

At this time, you need a Physical Web scanner app (available on iOS and Android) to read the URLs encoded in the Eddystone-URL. Estimote iOS and Android SDK also come with full support for discovering Eddystone-URL beacons, which you can add to your own app.

Eddystone-TLM packet is designed to be broadcast by the beacon alongside the “data” packets (i.e., UID and/or URL) for the purposes of fleet management. Nearby Bluetooth-capable devices can read these packets and relay them to a fleet management service—like the Estimote Cloud. This service can then notify the owner of the beacon that, e.g., the battery is running out. The telemetry packet consists of:

1. Battery voltage, which can be used to estimate the battery level of a beacon,
2. Beacon temperature,
3. Number of packets sent since the beacon was last powered-up or rebooted,
4. Beacon uptime, i.e., time since last power-up or reboot.

The Eddystone-EID frame broadcasts an encrypted ephemeral identifier that changes periodically at a rate determined during the initial registration with a web service. The broadcast ephemeral ID can be resolved remotely by the service with which it was registered, but to other observers appears to be changing randomly. This frame type is intended for use in security and privacy-enhanced devices.

4.3 Requirements

There are three requirements, all of them on a user's smartphone side:

1. It has to support Eddystone-URL (for Android, it must be Android 4.3 and above. On iOS it is supported by the newest version of Chrome).
2. It has to have Bluetooth turned on.
3. There should be an Internet connection (URLs are broadcast by Bluetooth, so this one isn't required to display links, but to actually open them).

4.4 Applications

Beacons have a vast variety of usage in the field of Mobile Commerce. Proximity marketing has become a rage with the help of Beacons only. Beacons have a large role in digitizing and bringing in the smartphone generation to the Brick & Mortar shops. Let us see in detail about the practical applications of the Eddystone beacon in various places.

1. Eddystone for App distribution:

You can use Eddystone to present your visitors with a link to your app on App Store or Google Play and encourage them to download it. And then once they've done so, the beacon will also broadcast a UID for the app to use.

2. Use the power of proximity with no app:

Using Eddystone-URL you can link to any page of your choice so you can power up your business with proximity even if you don't have your own app.

For example, if you're a restaurant, you may send a link to your online menu that shows up once someone enters your venue. Or, being a retailer, you may feature your current promotions, or display coupons when a mobile user is nearby.

3. Get and deliver more context

The third frame type that Eddystone broadcasts is Eddystone-TLM (Telemetry). It's sensor-driven data on the beacon's state and, possibly in the future, the environment around it. You could use that data to control temperature and humidity in your warehouse.

Telemetry would also enable you to trigger different actions based on various conditions. Therefore, depending on the weather, you could push notifications and invite passers-by to come by and have a cold drink or a cup of warming tea. In a hotel, you'd use that feature to adjust the temperature in rooms, based on conditions and particular guests' preferences.

5. Altbeacon : The Open and Inter-operable Proximity Beacon

The AltBeacon specification defines the format of the advertisement message that Bluetooth Low Energy proximity beacons broadcast. This specification is intended to create an open, competitive market for proximity beacon implementations. It is free for all to implement, with no royalty or fees. AltBeacon does not favor one vendor over another for any reason other than the technical standards compliance of a vendor's implementation.[7]

5.1 Data Spec



Fig. 2. AltBeacon data structure [3]

The AltBeacon advertisement makes use of the Manufacturer Specific Advertising Data structure as defined in Bluetooth Specification Version 4.0, Volume 6, Part B, Section 2.3 Advertising Channel PDU. The AltBeacon advertisement is made up of a 1-byte length field, 1-byte type field and two-byte company identifier, as prescribed by the Manufacturer Specific Advertising Data structure format, followed by 24 additional bytes containing the beacon advertisement data.[5]

5.2 AltBeacon Protocol Format

Offset	Offset	0	1	2	3	
Bit	Bit	0	1	2	3	
0	0	AD LENGTH				MFG ID
4	32	BEACON CODE				BEACON ID
8	64					BEACON ID (CONTINUED)
12	96					BEACON ID (CONTINUED)
16	128					BEACON ID (CONTINUED)
20	160					BEACON ID (CONTINUED)
24	192	BEACON ID (CONTINUED)				REFERENCE RSSI
						MFG RESERVED

Fig. 3. AltBeacon protocol [7]

5.3 Requirement

Since AltBeacons support iOS as well as Android devices requirements are more or less similar to beacon supportability with smartphones for iOS 7 or later, Bluetooth turned on, and a compatible iOS device[1]:

1. iPhone 4s or later
2. iPad (3rd generation) or later
3. iPad mini or later
4. iPod touch (5th generation) or later

For Android smartphones there are three requirements :

1. It has to support Eddystone-URL (for Android, it must Android 4.3 and above with Bluetooth 4.0 chipset.
2. It has to have Bluetooth turned on.

3. There should be an Internet connection (URLs are broadcast by Bluetooth, so this one isn't required to display links, but to actually open them).

5.4 Applications

AltBeacons provide a concise proximity advertising message for interchange of proximity information between advertisers and scanners. It maintains compliance with Bluetooth specification version 4.0 by utilizing defined advertising PDU and advertising data structures. It also enables the implementation of vendor-specific features.

6. GeoBeacon

This protocol appeared in 2017. This is an open-source protocol that can be used in the GeoCatching apps since it's very compact. GeoBeacon is a protocol specification that defines a message format for proximity beacon advertisements.[11]

6.1 Data Spec

The GeoBeacon advertisement makes use of the Manufacturer Specific Advertising Data structure as defined in Bluetooth Specification Version 4.0, Volume 6, Part B, Section 2.3 Advertising Channel PDU.

The GeoBeacon advertisement is made up of a 1-byte length field, 1-byte type field and two-byte company identifier, as prescribed by the Manufacturer Specific Advertising Data structure format, followed by 24 additional bytes containing the beacon advertisement data.[11]



Fig. 4. GeoBeacon data structure[11]

6.2 GeoBeacon Protocol Format

Offsets	Octet	0	1	2	3																												
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	EID LENGTH				EID TYPE				MFG ID																							
4	32	BEACON CODE								REFERENCE RSSI				VOLTAGE VALUE																			
8	64	NAC CODED COORDINATE VALUE FOR LATITUDE																															
12	96	NAC CODED COORDINATE FOR LATITUDE (CONTINUED)																NAC CODED COORDINATE FOR LONGITUDE															
16	128	NAC CODED COORDINATE VALUE FOR LONGITUDE (CONTINUED)																															
20	160	USER DATA																															
24	192	USER DATA (CONTINUED)																															

Fig. 5. GeoBeacon Protocol Format[11]

6.3 Requirements

GeoBeacon proximity beacon functionality is not limited to single-function devices, but can be incorporated as a feature of any device that is Bluetooth Low Energy compliant and which conforms to the requirements defined in Bluetooth Specification Version 4.0, Volume 0, Part B, Section 4.4 Low Energy Core Configuration or Section 4.5 Basic Rate and Low Energy Combined Core Configuration.

Devices that transmit proximity beacon advertisement packets are referred to as advertisers. Devices that receive proximity beacon advertisements are referred to as scanners. These roles follow the conventions defined in Bluetooth Specification Version 4.0, Volume 1, Part A, Section 1.2 Overview of Bluetooth Low Energy Operation [12].

6.4 Applications

1. Provide a advertising message for interchange information between advertisers and scanners specially designed for GeoCaching applications.
2. Maintain compliance with Bluetooth Specification Version 4.0 by utilizing defined advertising PDU and advertising data structures.
3. Provide TLM data, at least the battery value [12].

7. CONCLUSIONS

With the findings of the survey, it is safe to conclude that each beacon platform is unique in its application and it is up to the user to choose the proper platform for their purpose. If a user wants to work on an open source platform, Altbeacon would be the appropriate platform to choose. iBeacon and Eddystone have enormous application in advertising, indoor navigation, heat mapping, asset tracking and so forth. Limited information is available about

Geobeacon as it is still in its developmental phase. However, its main purpose is for advertising messages in Geocaching applications. To conclude, every beacon platform has a varied field of applications and needs to be chosen as per their requirement. Eddystone is a little superior in advertising as it also allows retailers and other advertisers to send entire web links through the beacon. Additionally it provides the ability to sense and transmit temperature data.

Our paper gives a brief description of all the platforms available for working with beacons. But this does not even begin to encompass the lengths to which beacons can be useful. They can also be a guiding force for the physically disabled. Blind people can navigate independently through the city with the help of beacons installed at prime locations. Deaf people can read the instructions passed on using their smartphones which they would have otherwise missed because of their disability. They would also be the main element in guiding people safely during emergencies in stadiums, malls, theaters. They would continue to operate in all conditions even when all other technology fails. All in all Beacons are a growing market with great potential and also economical and easy to implement. The following fig. 6. explains that the beacon installed base will consist of 4.5 million active beacons overall by year end 2018, with 3.5 million of these in use by retailers. [9]

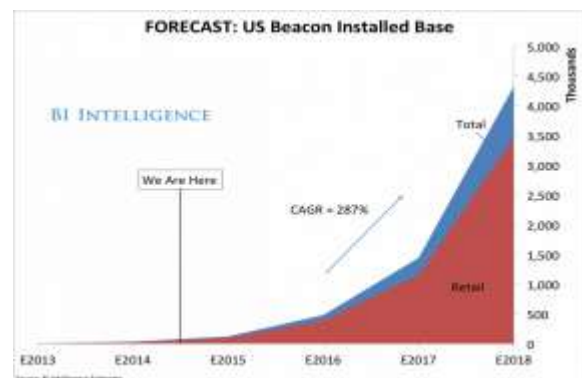


Fig. 6. Growth forecast of beacons in retail [9]

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