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Bluetooth Low Energy Technology, Beacon Composition, Evolution, and Application in Retail Store

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ABSTRACT: Exchange of data is a requirement on a daily basis in the modern world, irrespective of any field whether it's retail, IT, security, medical, traveling, news reporting, etc. Over the last few years beacon has been very useful in data transmission all over the globe due to the large number of IoT devices being available. Beacons are wireless and compact devices that require very little power consumption for functioning. Beacon itself is an IoT device, it works along with other IoT devices like smartphones, tablets, smartwatches, and other beacons, etc. Bluetooth Low Energy (BLE) Beacon is a transmitting device used for broadcasting signals to all Bluetooth user recipient devices available in the broadcasting bandwidth. They are very cost-effective and portable pieces of gadget. Beacons have been evolving and upgrading drastically due to their demand and usage in advertising, tracking, and positioning in businesses, public areas, and even indoor. The following work discusses the composition of a beacon(hardware), the framework of the beacon, major characteristics, history of beacon, how they evolve from the year 2013 along with various beacon models specifications, and the application of beacon in retail shops and malls, and how beacon proves to be very profitable in increasing the sales.

KEYWORDS: Beacon, Broadcasting, Data Transmission, Advertising Interval, Internet of Things.

I. INTRODUCTION

Bluetooth Low Energy (BLE) is a confined network technology. BLE is used to transmit information to nearby Bluetooth devices in the form of packages. It involves a system where one single provider can send the signals to many receivers without even getting connected to them. With BLE, the transmission of data becomes easy and efficient as there is no connection established between the sender and receiver so no password or login formalities are required, the data is just broadcasted to every Bluetooth device in the range of the sending portal.

In many years in the networking and advertising field, various methods had been performed to gather people's attention with the goal of maximum outreach, such as through ads, websites, journals, magazines, etc. But all these techniques work indirectly because they do not provide the content to the people there and there. For example: To know and get an idea about the content of a product, the person would have to search for the respective website, buy magazines, read articles or journals to understand the product and its details, so here BLE comes into play and breaks this barrier by directly impacting the people through broadcasting information to their nearby people via Bluetooth devices there itself.

Beacons are Bluetooth Low Energy devices used to broadcast signals to every Bluetooth device user present publicly that falls inside its range. Beacons are small IoT devices, very portable pieces of the gadget as they are wireless and light-weighted. As the name describes, they require very little power supply for functioning, as a result, they are preferred over any other technology when it comes to data transmission, tracking, and locating. Most of the beacons work on batteries. While functioning a beacon always has its range set up on its surroundings so whenever any Bluetooth device enters inside its range, the beacon detects the device and starts sending signals to it. There is a large availability of IoT devices everywhere, and a beacon's signal can be sent to any smartphone, laptop, tablet, smartwatches, etc.

The working of beacon technology can be referred to as the solar system, the sun can be considered as a beacon, and the rest all the planets as Bluetooth devices. As the sun mainly does only one thing that is to spread light and heat to its surrounding, the same way a beacon can be placed anywhere then it just does its simple job of transmitting data, and as the planets keep revolving around the sun, they receive light and heat provided by the sun same as the people which may enter into the beacon's range and keep moving around it randomly there receive signals from the beacons in the form of packages for free.

II. RESEARCH METHODOLOGY

BLE technology contributes in various fields like data transmission, advertising tracking and locating, news broadcasting, etc. BLE works along with IoT devices like smartphones, tablets, smartwatches, and beacons, etc. The use of these IoT devices increases by 25% every year on average. The number of IoT connections in the year 2010 was 12.5 billion, while today in 2021 the growth indicates that there are up to 46 billion connected IoT devices. Such drastic growth in production and usage of IoT devices acted useful for beacon applications everywhere. Data transmission followed by old methods like through blogs, articles, websites could reach up to limited people who took time as they were interested respectively. Beacon applications made it quick and simple giving every detail there itself on user's smartphones at any place inside proximity of a beacon. In the year 2016 the value of beacon technology was 519.6 million US dollars around the globe in near future time i.e., around 2025-2026 it can reach up to 56.6 billion U.S. dollars.

The data collection done here is based on previous studies that explained BLE technology's various applications, implementations, and frameworks. The beacon evolution is studied from the articles explaining iBeacon and its specifications from the year 2013 and different types of beacons that were later introduced, their specifications, and how they came into play. The application in a retail store is done here based on available surveys performed on the retailers using beacon technologies, the survey contained their feedback and how it helped them to increase their market. This type of research method provides detailed information and statistical updates on BLE and its overall background, present role, and future growth. The data collection method is performed by many experts and practitioners to gather legit information as it is efficient, resourceful, and reliable.

III. COMPOSITION

A beacon has a simple and tiny integrated circuit structure. If a beacon is to be diagnosed and opened for an internal view, there are neither too many wires nor there are several motherboards inside it. Most of the modern beacons are based on SOC (System on Chips), all the components are integrated on a single chip. The hardware of every beacon commonly consists of 3 basic components, they are:

1. CPU
2. Radio Transmitter
3. Batteries

CPU:

A beacon consists of an ARM processor, which is fast and very efficient and has 64-bit and 32-bit execution states for scalable and high performance. The beacon possesses Tightly Coupled Memory (TCM), Used for time-critical routine and provides a faster response time. This helps the beacon to transmit data quickly at regular intervals whenever a Bluetooth device approaches it.

for example: A low-power ARM CPU, 32-bit, 64 MHz in proximity beacon.

There is also an antenna attached to the ARM processor, it helps the beacon to broadcast electromagnetic waves with specific lengths and frequency.

Radio Transmitter:

It is an electronic circuit that does the key work of transforming electric power from a power source (In the case of beacon through batteries commonly) into a radio frequency alternating current to apply to the antenna, then the antenna radiates the energy from this circuit like a radio signal, these radio signals are made up of a combination unique IDs made up of letters and numbers transmitted on short regular intervals. The radio signals carry information packages that we want to display to the users.

Batteries:

Beacons often make use of small lithium chip batteries which are smaller and more powerful than AA batteries, beacons mainly use CR2032, CR2450, CR2477 coin-sized lithium batteries. Most of the modern beacons have replaceable batteries, so we can extend the lifespan of a beacon. The batteries are one of the most important components, as modern beacons work mostly on batteries only. Commonly the battery life of the beacon is between 18-24 months. Some of the large-size beacons consist of bigger batteries and therefore greater lifespan. Some large-size beacons have a lifespan of even 4-5 years.



The following image shows various beacons and their lifespan:

Compare beacons

Here are the main differences. All of them leverage the same, intelligent firmware, but their lifetime, form-factor or details differ depending on the application.

	 Sticker Beacon	 Proximity Tag	 Proximity Beacon	 Location Beacon	 Location UWB Beacon	 Video Beacon	 LTE Beacon
Built-in Radios	Bluetooth 4.2	Bluetooth 4.2	Bluetooth 5.0	Bluetooth 5.0	Bluetooth 5.0 UWB	Bluetooth 5.0 WiFi	Bluetooth 5.0 LTE-M/NB-IoT GPS/GALILEO/GLONASS
Default battery life	1 year	2 year	3 years	3 years	3 years	USB	2 years
Maximum battery life	1 year	3 year	5 years	5 years	5 years	USB	USB-C
Maximum Bluetooth range	7 meters	70 meters	100 meters	150 meters	200 meters	10 meters	200 meters
Supported use-cases	asset tracking	proximity, asset tracking	proximity	indoor location	indoor location	digital signage	asset tracking, vehicle tracking, proximity gateway
Thickness	6 mm	15 mm	25 mm	24 mm	27 mm	14 mm	16 mm
Length	29.66 mm	55 mm	69 mm	63 mm	75 mm	90 mm	90 mm
Width	28.44 mm	38 mm	46 mm	41 mm	50 mm	60 mm	90 mm
Weight	8-12 g	30 g	86 g	67 g	98 g	72 g	57 g
Recommended SDK	Estimote SDK	Proximity SDK	Proximity SDK	Indoor SDK	Indoor SDK	Mirror SDK	Web IDE
Fleet management	Estimote App	Estimote SDK	Estimote SDK	Estimote SDK	Estimote SDK	Cloud via WiFi	Cloud via LTE

Fig. Types of Beacons and their lifespan

Various SOC manufacturers like Nordic semiconductor and silicon labs provide BLE development kits, SDKs, and prototyping boards. Various modern beacons also include accelerometers, temperature sensors, etc.

IV. TWO MAJOR CHARACTERISTICS OF BEACON

1. Transmission Power
2. Advertising Interval

Transmission power:

It is the strength of the signal transmitted by a beacon up to a certain physical boundary reach. The signal containing data packages can be transmitted according to the beacon's transmission power. A good quality beacon has high transmission power. For an average beacon, the range of transmission is up to 50-70 meters. By defining such area coverage limits, the transmission power of a beacon is decided. This range of transmission can be increased or decreased for a beacon. The main factor that affects the transmission power is the power supply. A beacon with high power supply has a greater transmission power and can reach up to a longer distance range, with this the data can be transmitted to many people even at a longer distance. Therefore, transmission power is directly proportional to the power supply given. A powerful beacon can even reach up to 300 to 400 meters of transmitting range. Beacons that require low power consumption have a small range of data transmission but less power is consumed so the lifespan of such beacons is maintained. For example, coin size beacons have small batteries and have less transmission power, their life span is up to one to two years and further extendable.

Advertising interval:

It is the number of times the signal has been transmitted in a certain time period over a transmitting area. For example, a beacon transmitting signals five times in a second. Advertising interval is a major functionality of Beacon as it describes its performance, that is how many times a beacon could transmit signals or a range. A beacon having a high advertising interval that is 10-20 times a second is a very high-performance beacon, but such beacons have a shorter lifespan because they require a constant power supply. Due to the constant broadcasting of signals at high advertising



intervals, the battery runs down very fast. A beacon that has a low advertising interval has a longer lifespan as the power supply is utilized at a lower rate, that is one or two times per second. Therefore, the advertising interval is inversely proportional to the lifespan of Beacon. But the beacons with low advertising intervals are considered to be low-performance beacons and such types of beacons are not suitable for many places. A beacon with a high advertising interval keeps the attention of the people towards itself and broadcasts the signal faster so that the people can get constant information and updates on products. Such high-performance beacons are used at shopping malls to let people know about the best deals of the day quickly.

V. EVOLUTION

History of BLE:

In the year 1989, Bluetooth technology was originally created by Dr. Nils Rydbeck and Dr. Johan Ullman firstly. From that time till now Bluetooth technology has been used in many places and has proved to be a beneficial technology. By the time many updates occurred in the technology with added features like better and fast performance with high frequency. The Bluetooth version 2.0 was created in the year 2005 and version 3.0 in 2009 both the versions required bidirectional (two-way) connection to work, due to which by no choice the devices had to connect with one another at regular intervals for communication.

In the year 2010, Bluetooth came up with unidirectional (one-way) technology which was called Bluetooth Smart or Bluetooth Low Energy (BLE) as the version 4.0 of Bluetooth, by this unidirectional technology the devices could easily transmit data like a sender, there was no need for any connection to be established with other devices for data transmission.

Various Beacon Models

1. iBeacon:

In the year 2013, Apple introduced its first beacon called iBeacon as a part of iOS 7. The iBeacon was introduced during the Worldwide Developer Conference (WWDC). With the iBeacon model, smartphones and tablets could receive signals emitted from the beacon present in the physical world through mobile apps and respond respectively. This technology proved so useful that within a year top 50 US retailers started using it in their shops for product advertising and feedback collection. They make use of Manufacturer Data Advertisement data type to transmit data. The range of a standard iBeacon is 70 meters and for long distances it is up to 450 meters. The iBeacon comes in their standard size, Universal Serial Bus (USB) model, and even small coin-sized beacons. The lifespan of an iBeacon ranges between 12-24 months. By default, an iBeacon having a 100 meters advertising interval with a coin cell battery lasts up to 1-3 months. An iBeacon is very simple to implement because of its basic structure and characteristics.

2. Eddystone:

In July 2015, Google introduced Eddystone- EID (Ephemeral ID), It was based on a cryptographically firm method of setting up a beacon for data broadcasting. The data emitted through it could only be accessed by authorized people. They make use of the Service Data Advertisement data type for data transmitting. With this model, the beacons can report their capabilities to the app. It has more features than an iBeacon as it connects a beacon with the physical world but compared to other beacons it is a little complicated to integrate. At present time google has almost abandoned Eddystone standards for android smartphones particularly on google chrome which is a big search engine but still, it can be considered as a great option for applications where both transmitting and receiving ends are handled by the same user.

3. AltBeacon:

In July 2014, the AltBeacon was introduced by radius network. It makes use of defined advertising PDU (Protocol Data Unit) and advertising data structures. Being an open-sourced beacon, it was designed to resolve the issues of protocols choosing one vendor over the other. It is quite compatible with various mobile operating platforms like Android, iOS as it allows even Android devices to use beacons the way iOS devices access it. Any kind of usual implementation restrictions is tried to avoid completely so that the interested parties or companies get encouraged for its implementation in their projects. Very flexible to use anywhere. Also, changes can be done in their source code for modification according to the user's needs.



4. GeoBeacon:

In July 2017, tech world Tecno-World introduced GeoBeacon. It is also an open-source beacon. It also makes use of defined advertising PDU and advertising data structures. For a set of two high-resolution coordinates space is being provided by GeoBeacon. The main purpose behind this model was for the usage in Geocaching applications. The data stored here is in a very compact format. The model had great battery life supported by TML-Data (Tadiran Lithium Batteries).

VI. APPLICATION IN RETAIL STORE

Beacons are designed with the purpose of broadcasting information about anything whether place, item, food, etc. It works with an ideology to get people attracted towards itself by providing them complete information for free by just using a mobile application. A retail store is a place where many products are available with each product having many pieces stored, a place like this is perfectly suitable for beacon functioning because they already got products just kept racked for the customer and it is not always possible to keep a person at every single point in the store providing information about the products to the customer at every minute for a whole day, so here beacons come into play because the basic job required here is to get people attracted towards the products and provide details regarding it.

Here's how it works, whenever a customer enters into a store carrying their smartphones, while shopping, when they enter inside the range of any beacon placed inside the store, the beacon detects those Bluetooth devices (smartphones, smartwatches) and it starts emitting signals to the customer by knowing their location and providing them information about the associated app of the store for this the beacon doesn't require to connect itself with any of these devices it just sends them notifications. It depends upon the retailers what data they want to send to the customer through a beacon, it can be about a certain spot or product inside the store or it can be about the whole store or both as the retailer is at the server end of the application. The beacon's applications have changeable source code. Thus, changes can be made as per the user requirement which makes it flexible to use it anywhere in the store. According to the customer's movement and location wherever in the store, the retailers can send notifications on their devices with clear focused messages like availability of products, offers, products that are newly restocked. The app also helps the retailers to keep track of the customers what they usually purchase more or less, by this the retailers already got an idea about which products need to be restocked regularly and which don't. They get to know about their shopping trends and their shopping behaviour which helps a lot to the retailers as they know about people's choices, this is like an indirect communication between the retailers and the customer through beacon transmission and a beacon app linking them. The retailers can organize the store accordingly, increase their sales, and communicate to the customer on a regular basis. This makes both shopping and selling a fun experience and the customers would not have to worry about the product or ask questions about it to the seller, as they get everything on their app. Customers can even pay through the app itself.

VII. RESULT AND DISCUSSION

BLE technology has been used since the year 2013 in retail stores and also in other fields too. Even though it came into major play from the year 2013-2015 the technology is still fresh as updates occur with it with every new model of the beacon. The beacon changed a lot from the bigger router size to now even coin size. The reach of the beacon has grown drastically even though it is used for subjecting to nearby objects (around 20-30 meters), many modern beacons which have high transmission power can send signals up to 70 meters and even at a distance more than 100 meters range, such type of beacons can be used in big companies, go-downs and in large size retail stores to provide information from one corner to another. The batteries are replaceable which is a great benefit as the same beacon can be used over and over again. The biggest benefit is its low cost compared to any other technology because very low power is required. Hence big companies and even small companies do not hesitate to take the risk of using beacon technology.

There are certain limitations regarding the battery-life of a beacon, A beacons at places where high advertising intervals are required and the messages need to be sent at every second to hundreds of people at greater range due to this the battery drains down fast, but this problem can be resolved by implementing an RTC (Real Time Clock) feature with this we can set up a beacon on power-saving mode so at times like when there is less availability of people or during off times and the data transmission is not required at a greater extent, then we can put our beacon on sleep mode this saves its battery life.

A Beacon transmits signals to everyone and any Bluetooth device can receive it, but sometimes the data transmitted from the beacon needs to be confidential and should only be received by authorized people. In such cases, special IDs must be allotted to the data packages which are being transmitted, so the unwanted user wouldn't be able to access the data and security of the data will be maintained.



VIII. CONCLUSION

Bluetooth low energy technology (BLE) is very efficient when it comes to advertising goods or products of any kind all over the globe as IoT devices are available everywhere in abundance. Bluetooth devices are no longer remained restricted to smartphones or tablets, gadgets like smartwatches, health-monitors, smart television sets, big display screens at malls in metropolitan cities, or projectors for E-Classes all possess the Bluetooth functionality all in all any wireless device that we may encounter today may have Bluetooth functionality, a beacon can recognize any of this device and spread data signals easily. As beacons are wireless and have a small size they can be implemented anywhere, for example, in corporate sectors at any wall, in-retail stores at any corner, or special USB Beacon which can be kept plugged in. Even a mobile phone can be a beacon (moving object) and its range will move along with itself wherever it goes, covering different areas and transmitting signals to many people. The major factor which makes this technology so convenient is less power consumption compared to any other technology. Some of the beacons have a lifespan of up to 4-5 years which is very reliable. Also, many beacon lifespans can be extended since the batteries are replaceable. Hence it is a very useful technology and it saves a lot of electricity, requires very little space, is cost-effective, and increases the business profit by spreading information, tracking records, and collecting feedback.

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