# Advanced Bluetooth 4.0+ based Smart Lighting Technology

Smart lighting and lighting controls are not restricted by hardware or traditional lighting control protocols anymore. Today, system modifications and firmware updates can all be done over-the-air. Wireless technologies enable lighting controls in places where it was not an option before. Besides Bluetooth, Zigbee and WiFi there are proprietary technologies in use. Saara Guastella M.Sc. in Lighting Engineering and Lighting Controls, is Product Marketing Manager at Casambi. In the following article she introduces Casambi's technology based on Bluetooth Low Energy, and describes, explains and compares it with other established communication technologies for smart lighting.

Many of us remember Bluetooth Classic from our first mobile phones; the battery consuming, wireless alternative to RS-232 cables, invented by Ericsson in 1994. It is important to understand that Classic Bluetooth and Bluetooth Low Energy are not the same thing. Bluetooth Low Energy is not just another Bluetooth revisionn - it is a completely new technology.

Bluetooth Low Energy, also called Bluetooth 4.0+, Bluetooth Smart or simply BLE, was originally designed by Nokia as Wibree before being adopted by the Bluetooth Special Interest Group (SIG) and published in 2010. The low energy functionality of BLE allows developers to make products that run on small coin-cell batteries or energy-harvesting devices, making BLE a good protocol to be used in wireless lighting control applications.

## A New Technology Approach

The new wireless lighting control solution is based on BLE but it is not just a wireless lighting control system; it is its own technology. On top of BLE, this technology provides a mesh network where all the intelligence of the system is replicated in every node and, in such a way, creates a system with no points of failure. Such a self-healing and self-organizing wireless mesh network can control a large number of fixtures from any point. It also allows for firmware updates over the network, allowing any kind of changes to be made over-the-air and, in that way, to be truly wireless. In this kind of fully distributed and symmetric architecture, any unit can go offline and catch up to others when they return back online. Internet connection is only needed for user interface configurations for smartphones and tablets via cloud service.

An implemented firmware-over-extension-interface offers unlimited possibilities on what can be controlled/reported from the system to the client's user interface. The technology works with any manufacturer's range of existing luminaires or already installed wall switches but can also be easily integrated into LED drivers, LED bulbs or LED modules.

## Essential Distinguishing Marks

### No gateways
BLE was built for Internet of Things (IoT) and has been implemented in smartphones and tablets since the beginning of 2012. This means that no gateway modules or any kind of dongle is needed to control lighting via BLE, which makes a BLE - based lighting control solution more cost effective than solutions built on other wireless technologies. Other technologies, like WiFi and Zigbee, require a gateway module between the control device and the network.

### Solving interference issues
WiFi, Zigbee and Bluetooth all operate on the 2.400 - 2.4835 GHz ISM band. However, BLE is more robust and not as sensitive to interferences as WiFi and Zigbee. WiFi uses Direct Sequence Spread Spectrum (DSSS) and therefore

does not hop or change frequency but remains centered on one channel that is 22 MHz wide. While there is room for 11 overlapping channels in this 83 MHz-wide band, there is only room for three non-overlapping channels. Thus there can be no more than three different WiFi networks operating in close proximity to one another.

For each WiFi channel, there are four overlapping ZigBee channels, as Zigbee breaks the band into 16 channels. Zigbee also uses DSSS as WiFi. When a WiFi network is on the same channel as a ZigBee network, the WiFi network will usually interfere with the ZigBee network. As a Zigbee lighting control solution also needs a gateway for a smartphone or tablet solutions, and as this gateway in most cases is WiFi, some serious coexistence problems are to be faced.

BLE operates in a different manner than WiFi or Zigbee. BLE uses Frequency Hopping Spread Spectrum (FHSS) which means it hops between channels to counteract interference problems. BLE specifies 40 channels, separated by 2 MHz, of which 3 channels are used as advertising channels and 37 are used as data channels.

## Single point of failure

A single point of failure (SPOF) is a critical part or component of a system that, if it fails, will stop the entire system from working. SPOF are, for example, routers, proxies or other physical or virtual web or application nodes. A comparison of the network topology and setup of WiFi, Zigbee and BLE shows that WiFi and Zigbee solutions are not as reliable as BLE-based solutions, as shown in figure 1.

## Proximity sensing

A technology that BLE enables, which is not possible with Zigbee or WiFi, is the Beacon technology. Beacon technology enables location
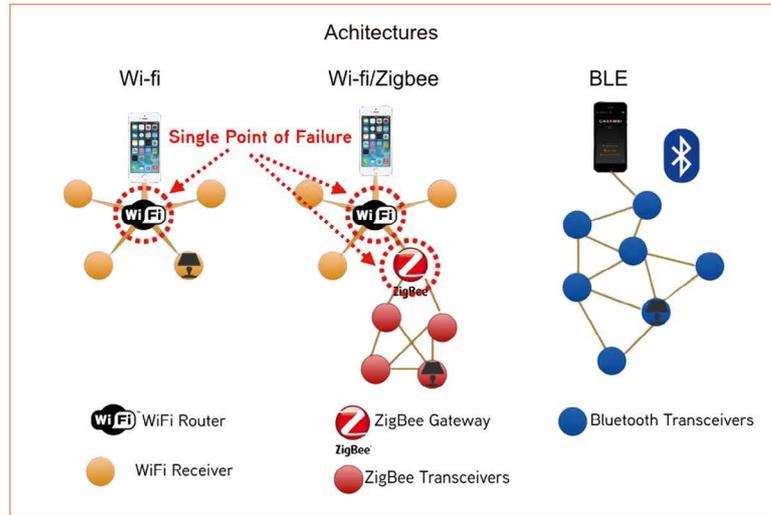
awareness and acts based on proximity estimations. A beacon establishes a region around it and understands when a beacon-receiving device has entered or left this region based on proximity information. A device entering the region can determine if it wants to receive the information sent to it or not.

Beacon transmitters could be placed basically anywhere, but it is quite logical to place them inside luminaires. Luminaires already cover the whole area people move around in and they already have their power installed in the building. Luminaires also tend to light up some kind of object and whether the object is a piece of art in an art gallery or a car at a car retailer, a beacon receiver can trigger an app to display information about the object in question. If beacon technology is already integrated in lighting modules, no additional investment needs to be done for these services.

## How the iBeacon Technology Works

BLE communicates on so called "advertisement channels" where small packets of data are broadcasted at regular intervals. This kind of advertising is also called beaconing. Devices like smartphones can be used to collect the sent data and use it for a variety of applications to trigger actions or push messages.

Apple introduced iBeacon, a protocol based on BLE for advertising in 2013.

An iBeacon advertisement provides the following information via BLE:

- **UUID:** A 16-byte Universally Used Identifier string used to differentiate a large group of related beacons
- **Major:** A 2-byte string used to distinguish a smaller subset of beacons within the larger group
- **Minor:** A 2-byte string meant to identify individual beacons
- **Tx Power:** Used to determine proximity (distance) from the beacon. It is defined as the strength of the signal exactly 1 meter from the device

### Example:

A computer shop chain has different discounts in different countries. The computer shop chain has an app that listens to iBeacons and the chain wants to inform its clients of the relevant discounts for the app users. The computer shop would define a unique identifier, the UUID, which only their app will react to. Therefore, the UUID would be specific for the computer shop chain, but the same in the whole of Europe. The major value of the beacon would be different depending on the country. The minor value would be different depending on where in the shop it is situated. One beacon transmitter would be by the laptops, one by the screens and one by the cables. A person entering a computer shop

**Figure 2:**
A typical Bluetooth 4.0 lighting mesh network configuration



**Figure 3:**
iBeacon technology allows different levels of interaction at each range
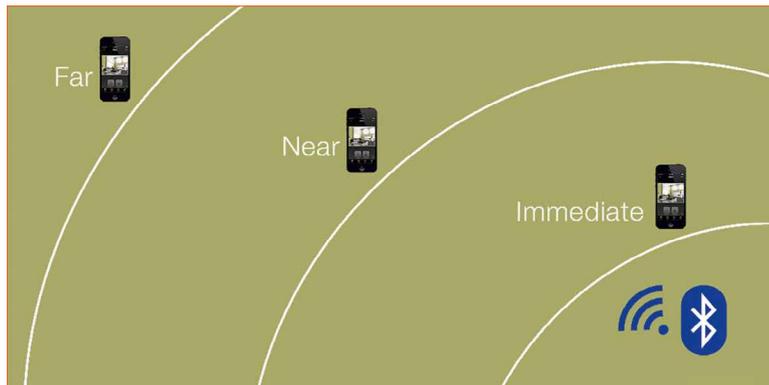


of that particular chain in Spain and walking by the computers would get a message that a specific computer is on discount, while a person entering the same chain's computer shop in Norway would get a discount notification on another product with another price and currency. As the same user would walk over to the area of computer screens, another message would pop up.

When a device detects a beacon signal, it uses signal strength to determine the proximity, as well as the accuracy of its estimation of proximity to the beacon.

The estimate is according to one of the following four states:

- **Immediate:** A high level of confidence that the device is physically very close to the beacon. Very likely being held directly up to the beacon.
- **Near:** Proximity of about 1-3 m
- **Far:** This state indicates that a beacon device can be detected but the confidence in the accuracy is too low to determine either Near or Immediate
- **Unknown:** The proximity of the beacon cannot be determined

Obstacles between the beacon and the receiving device can affect the signal strength. As mentioned before, the four states are not only based on proximity but also the accuracy of the estimation. For example, "Far" does not necessarily mean that the device is physically far from the beacon, it can also mean that the accuracy has been affected.

## Applications

Well-suited applications for iBeacons are museums and retail. Instead of using an audio guide the museum visitor can download a museum app that is able to receive information from beacon transmitters. These units can be placed, for example, in the driver of the luminaire and the luminaire would obviously be lighting up a piece of art. When the museum visitor is in the proximity of the art piece his/her app will display the information on the piece that has been sent by beacon technology over BLE. In retail applications, beacon technology allows marketing and guidance, information on happenings and discounts in the stores to be sent to smartphone users.

In the lighting application this kind of proximity sensing technology can be used for triggering lighting scenes. Not only predefined scenes that are common in the lighting control industry but actually user-specific scenes. Lighting can be used for guidance, to find the right path to the end goal where the user is heading to or as a "follow me" functionality; meaning that lighting is turned on only where the user i s situated and needs it.

Beacon technology could be used in car parks as navigation help to find where a car was parked, in coffee shops and kiosks for ordering processes, at airports for gate navigation, in zoos to provide information on animals or at bus stops to tell the timetable for buses at that particular bus stop. As the technology enables location awareness and knows when a user enters or leaves a certain area there are an enormous amount of benefits from this technology.

## Security

GPS and GSM based location services are widely used for outdoor applications. However, they do not work very well indoors. The location platforms that BLE enables for indoor applications gives a lot of opportunities. It is also important not to mix beacons with GPS locations. A beacon is not a physical location; it is a transmitter that can be placed anywhere and have its location changed at anytime, while GPS locations are always there, forever fixed and public for everyone. iBeacons have a unique identifier: If the receiver does not know this UUID, it will never know it is there.

iBeacon technology is also different from other location-based technologies as the transmitter only sends out one-way communication. This ensures that only a user that has installed an app that can

receive that particular beacon's information will receive it. The user must not only have installed the app but also given permission to the app to listen to beacons. This means that the user gives the permission to the app to track the user. As the beacon technology is not based on two-way ommunication, this means that no beacon transmitter can track users as they walk past transmitters.

## Conclusion

The lighting and the lighting control industry is being disrupted by semiconductors, software and wireless technologies. New players on the market overlook traditional lighting control protocols and introduce sophisticated wireless lighting control systems to the market that provide for the same, if not for more, functionalities and with more benefits.

"Why now?" many might wonder. Before the launch of Bluetooth Low Energy there was not a well-suited wireless protocol that would have enabled all the functionalities and benefits that BLE does. The fact that BLE is integrated in smartphones and tablets is the core benefit that makes BLE a mainstream, most cost effective and the only truly future proof of the wireless technologies. ■