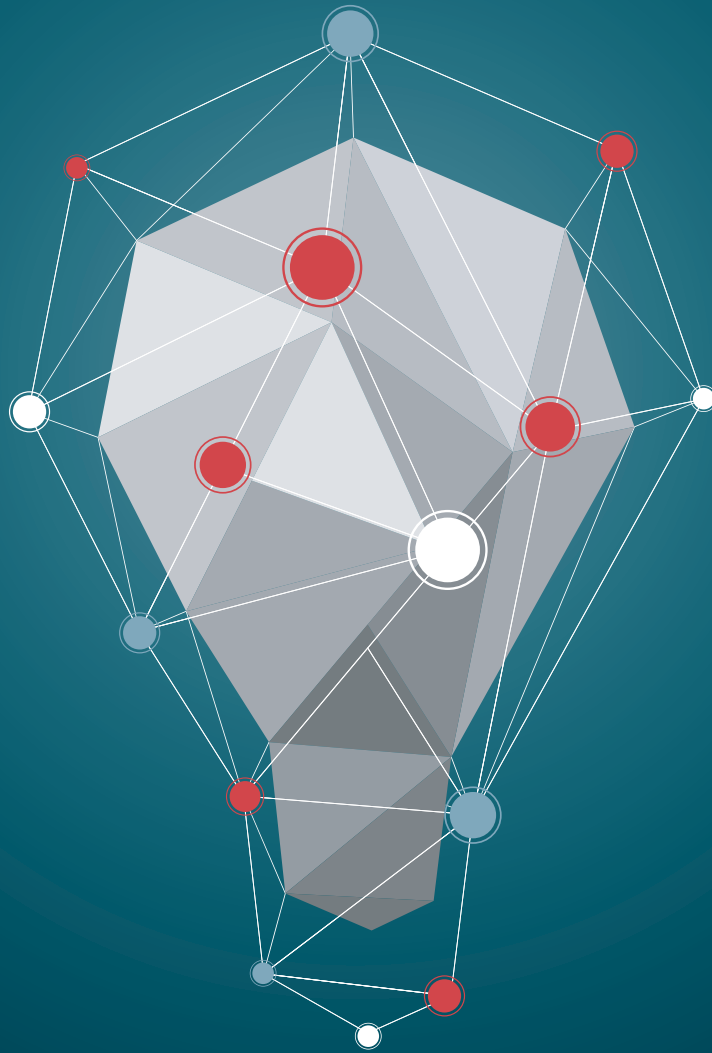


Enhancing Smart Lighting with 802.15.4 Mesh, Bluetooth, and Multiprotocol Connectivity





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Prime Time for Solid-State Lighting Differentiation

For the estimated \$19 billion smart lighting market to reach its potential, lamps, luminaires and lighting controls need more functionality than just on/off. Light-emitting diodes (LED) are needed as the light source, while the ability to dim, tune colors, automate, and enable remote control of the lighting system is expected. With additional wireless connectivity and two-way communication, lighting can become an efficient and scalable Internet of Things (IoT) backbone that offers differentiated solutions.

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As lighting becomes part of larger and larger networks, differentiation beyond energy reduction become possible. Enhanced user experience during installation, commissioning, and reconfiguration is possible with a front-end using Bluetooth and mobile devices. Improved zone control, far field voice monitoring, and beaconing is made possible by using new and existing lighting infrastructure.

The solid-state lighting (SSL) market is going through phases of embedding sensors, adding connectivity, and becoming part of larger ecosystems. By increasing the traditional lighting functionality, lamps and luminaires are no longer immune to cumbersome installation or poorly implemented connectivity. Wireless connectivity allows lighting infrastructure to form scalable mesh networks. These networks can be locally controlled by end-users and monitored by building management systems to optimize use and energy consumption. Smart lightbulbs today are not measured by their classic capabilities or how well they light up; they are more often rated based on software performance and additional usability.

Introduction

In this paper we look at opportunities for differentiation in the intelligent lighting market. Multiprotocol connectivity is one of the pieces that let manufacturers distinguish themselves. Wireless multiprotocol makes it possible to simultaneously combine protocols like [Zigbee](#) with [Bluetooth®](#) on a single chip through intelligent time-slicing. Used together, a lamp can communicate with established Zigbee mesh-enabled devices while providing Bluetooth beaconing and smartphone-enabled light control. Hardware supporting multiprotocol and developer tool features to consider when selecting a platform for designing control and lighting systems are also examined.

Lamps and luminaires (defined as a complete light unit that includes LED light sources and drivers) are up for a major revision. The traditional lamp and light source is becoming an advanced computer system capable of reacting and communicating with its surroundings. Embedding sensors, adding connectivity, and becoming part of larger ecosystems and business analytics are ingredients necessary for full differentiation in the smart lighting market.

On the Path to Smarter Lighting

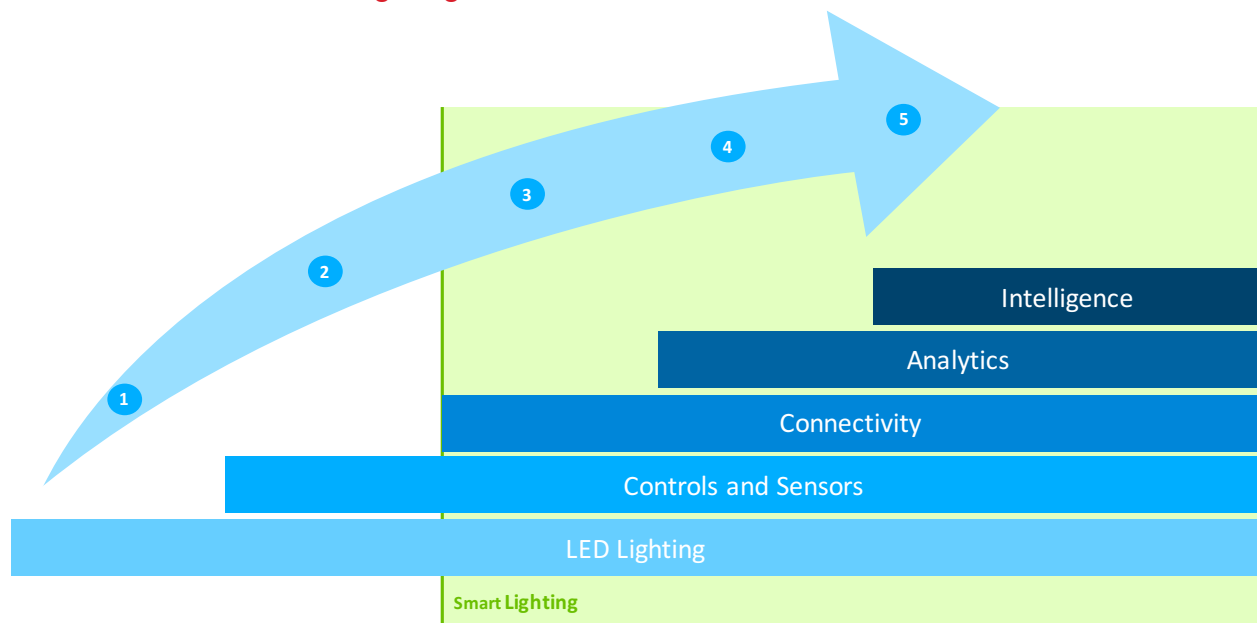


Figure 1: Gartner outlines 5 phases for smart lighting. Many manufacturers are just now starting to add connectivity.

By incorporating a microcontroller (MCU), a lamp for home can offer different settings without changing any infrastructure. The lamp is programmed to change color from warm red to cool blue in an instant. Philips' Scene Switch LED lamp cycles through predefined color settings by monitoring how the user flicks the existing light switch. Adding a proximity sensor to the lamp or switch, like Sengled's SmartSense, turns existing fixtures into security or follow-me home lights.

In buildings and retail spaces, high-end luminaires may include temperature and light sensors that automatically adjust the driver current. Embedding sensors ensures a consistent color temperature and perceived light quality can be maintained while extending the LED lifetime. External or internal light sensors provide a way to perform daylight harvesting by sampling and measuring the ambient light. The result is overhead lighting that dim and adjusts dynamically throughout the day to both preserve energy and provide a consistent experience.

Because lamps and luminaires are so widely deployed and have access to power, they appear to be the perfect vehicle to deliver additional functionality. Residential and consumer benefits range from zonal automation to simple voice controls. In retail and commercial settings, location services and personalized beaconing, space utilization, and

sub-metering are potential value-adds. Integration with analytics and cloud services enable additional professional services, and represent the final piece of a smart lighting system.

Improving The Function of Lights

Before Solid-state Lighting, the lighting infrastructure had one task; provide light. Today's emerging smart lighting market makes it possible to introduce new and innovative ways to use lights to collect and act on data.

Adding Bluetooth Beaconing

[Bluetooth advertising and beaconing](#) functionality provides proximity-awareness, and it's a popular application in retail, industrial, healthcare, and some home applications. Retailers can use Bluetooth-enabled beacons to provide seamless shopping experiences or navigation aid. Asset tracking, utilization, and automation are also made possible with the beacon technology. Unlike RFID, Bluetooth beacons are powered devices that actively broadcast information that can be received by Bluetooth-enabled devices like smartphones. Some of the common frameworks for beaconing include Apple's iBeacon and Google's Eddystone. With the latest [Bluetooth 5](#) specification, beacons can broadcast both iBeacon and Eddystone advertisements, making the beacon technology suitable for greater adoption.

A challenge for the growing beaconing market is the deployment and management of beacons. The number of beacons needed, where to place them, and their battery life require planning and support. By incorporating beacons into lighting, a greater density of beacons can be deployed to provide more accuracy. In addition, a multipurpose device such as a light fixture with beacon and advertising capability can reduce the number of connected devices that must be installed and managed.

A Better Beacon

Knowing the location of each luminaires makes lighting a great host for beaconing, asset tracking and improving retail experiences. Instead of having to install both connected lights and beacons, a connected lamp or luminaire can serve as the means to deploy a robust Bluetooth beacon infrastructure. A Zigbee mesh network can serve as the connected lighting communications and automation backbone while simultaneously supporting Bluetooth beaconing to support additional use cases such as asset tracking and retail advertising. This can provide a more cost-effective means to improve beacon density than deploying separate dedicated Beacon devices. With access to power it is possible to overcome the logistical challenges with management of battery operated beacons in many scenarios.

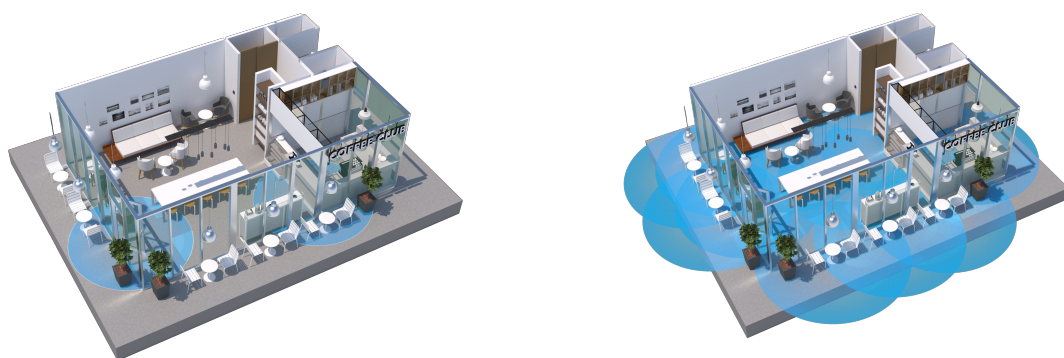


Figure 2 Increasing beacon density by incorporating beacons into lighting

Airports with Bluetooth beacon-enabled luminaires have a unique possibility to provide customers with real-time traffic notifications and gate-guidance. Better office space utilization and sub-metering options are some of the benefits for medium and large building management. Healthcare applications include patient benefits like faster check-in, location aid, and quality of the light. Smart lighting enables tailored settings for improved sleep or even pain relief based on the patient status. Lamps and luminaires can also report patient activity and position as a safety measure. In residential settings, home automation is made possible with a beacon-enhanced mesh network. Bluetooth enabled

outdoor lights or smart door locks can trigger scenes in a house by communicating directly with the light system. As the user moves through the house, lamps can perform advanced occupancy automation based on the user's movements.

Advances in [multiprotocol](#) software and hardware provide a cost effective means to add beacon functionality to luminaires using a single radio and SoC. Instead of requiring two dedicated chips, one for Bluetooth and one for mesh connectivity, the same device can be used to implement multiple wireless protocols. This approach can reduce the overall wireless sub-system cost by 40% by using one radio and SoC and also simplify PCB design by eliminating the need to address the possible interference between two radios in a design.

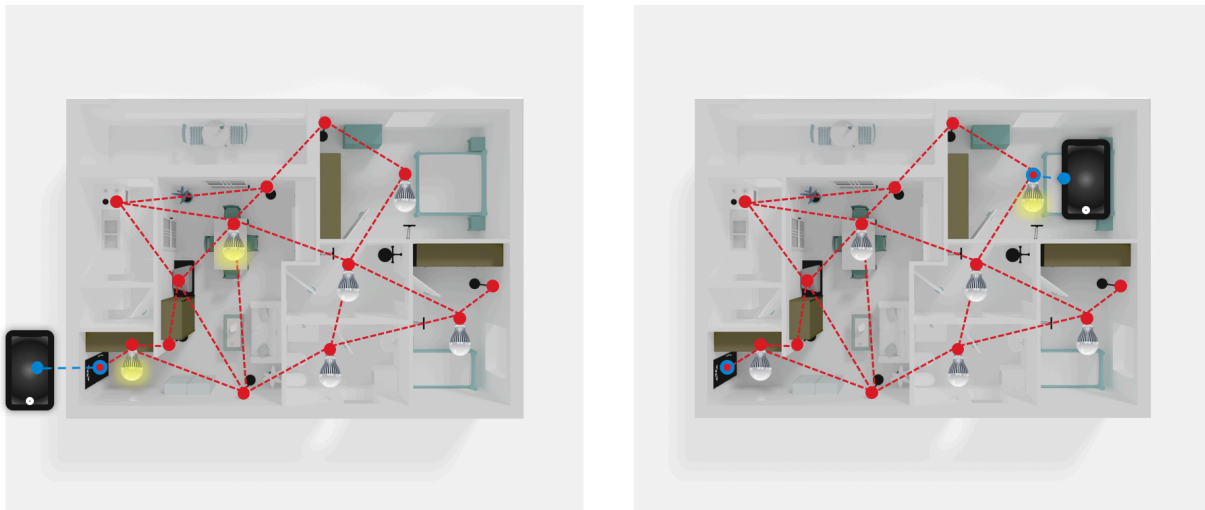


Figure 3 Enhancing consumer experience in the home with Bluetooth beacons

Improving Lighting Setup and Management

Installing and adding new products like lamps or luminaires to an existing lighting network can be time-consuming and potentially costly. For residential applications, the cost normally equals the time the user needs to spend getting their lamp up and running. In most mesh-based networks, a lamp needs to join the network securely by pairing the lamp to a control unit like a wireless switch or remote. A caveat is a limitation to how many devices the control unit can handle.

In larger systems the dedicated control unit might be supported by a dedicated gateway or hub as the interface for adding new devices. A gateway offers various ways for commissioning of a new lamp. Normally a user can control the procedure via a connected computer or mobile device connected, while the lamp is running on the separate lighting network. Amazon's latest smart home hub makes it possible to discover and add new devices via voice commands. Like Philips Hue Bridge, Wink Hub, and SmartThings, Amazon's Echo Plus includes Zigbee support and can control and interact with other Zigbee lamps and switches.

Accessibility to the infrastructure, the sheer number of devices in addition to external factors like interference from other networks, makes commissioning in industrial and commercial settings different than the home network. Installing, adding, moving, and configuring luminaires in buildings, industrial or commercial settings requires more resources and planning. Professional setup therefore often involves an onsite technician that identifies and programs lights into their respective zones or groups after the lights have been installed.

Security and Setup Time

In addition to lowering the energy consumption compared to conventional illumination solutions, wireless LED lighting solutions have inherit benefits that reduce users investments compared to wired systems. Less lighting control lines and components can reduce the installation cost by 50 percent in larger installations. Wireless lighting solutions also provide commissioning benefits.

By adding Bluetooth LE support to lights on a Zigbee mesh network, luminaire setup experience can be simplified via apps on smartphones or tablets. From a security perspective, Bluetooth can also work as a way to enhance security. Lighting manufacturers that provide multiprotocol effectively give their users an out of band commissioning portal for the lighting mesh network.

Providing Direct Control

By addition Bluetooth connectivity, it's possible to extend what and who can control lights. Without involving technicians, individuals can optimize room or office space properties to their needs. With more focus on human centric lights, being able to adjust settings or scenes can help individuals feel and perform better. The same is possible in smart homes. Without the need to access a gateway, users can add and control lamps simply by using their smartphone's Bluetooth connection.

If manufacturers provide a properly implemented smartphone application, integrators and installers can easily push location settings directly to the light nodes. High-end solutions today provide the possibility of making the new or updated lighting installation compliant to building and energy efficiency regulations like ASHRAE, Title 24, or IECC directly from the installers mobile device.

Monitoring and Improving System Health

Although LED lights provide much longer lifetimes than its incandescent options, there are times when lamps and luminaires fail. During manufacturing, a multiprotocol solution enables Bluetooth connectivity for configuring and testing the luminaire and the Zigbee mesh network. Manufacturers can also provide better warranties for their customers by ignoring time spent on shelves and not actually installed. This makes it possible to provide actual installed runtime guarantees, and it gives manufacturers better insight to the use of their luminaires.

Post installation, multiprotocol enabled Bluetooth beacons enable users to check the health and status of the luminaires and the lighting network directly via a smartphone. The application can warn when it's time for service, replacement or if updates are needed. With 2-way communication built-in, Lighting as a Service, subscription-based lighting, becomes a viable option for integrators and customers concerned with larger one-time investments.

Enabling Updates in the Field

With the multiprotocol hardware already integrated, lighting manufacturers can provide improved commissioning and control benefits out of the box. Via over-the-air updates (OTA), functionality can later be enabled or disabled, making longer term business relationships possible. OTA makes it possible to optimize beacon range by turning on or off the number of beacon-enabled luminaires. In-store navigation and useful instructions, tailored offers, zonal specific items, and payment reminders are some of the user benefits.

Combining Multiple Wireless Standards into Lights

Advances in software and hardware technology enable us to deliver the enhancements in lighting outlined above with a single SoC and radio through multiprotocol wireless connectivity. Being able to program a chip in production to support Bluetooth low energy, Zigbee, or a proprietary protocol allows luminaire makers to potentially address different markets. Such a future proof solution also gives manufacturers peace of mind.

Why Choose Multiprotocol Connectivity

Mainstream customers rarely purchase a smart product based on a particular wireless protocol, but manufacturers that fail to provide ease of use and stable connectivity might experience short-lived brand loyalty and device returns. By supporting multiple wireless protocols, lighting manufacturers can benefit not only from a reduced BOM cost but also adding new capabilities such as beaconing and simplifying existing commissioning and control routines (see table).

Feature	Bluetooth LE	Zigbee	Multiprotocol
Low Power	✓	✓	✓
Beaconing	✓		✓
Global Frequency	✓	✓	✓
Self-Healing		✓	✓
Topology	P2P/Star	Mesh	Mesh, P2P, Star
Smartphone	✓		✓
Area Coverage	Low/Medium	Medium/Large	Medium/Large

Table 1 Combining the benefits of Bluetooth and Zigbee makes Multiprotocol suitable for lighting.

Running Multiple Protocols on a Single Radio

A multiprotocol approach opens up new use cases, especially when combining Bluetooth low energy with other wireless protocols. Some of the benefits that Bluetooth and Zigbee provide when used separately can be combined to give lighting manufacturers an edge in the lighting market.

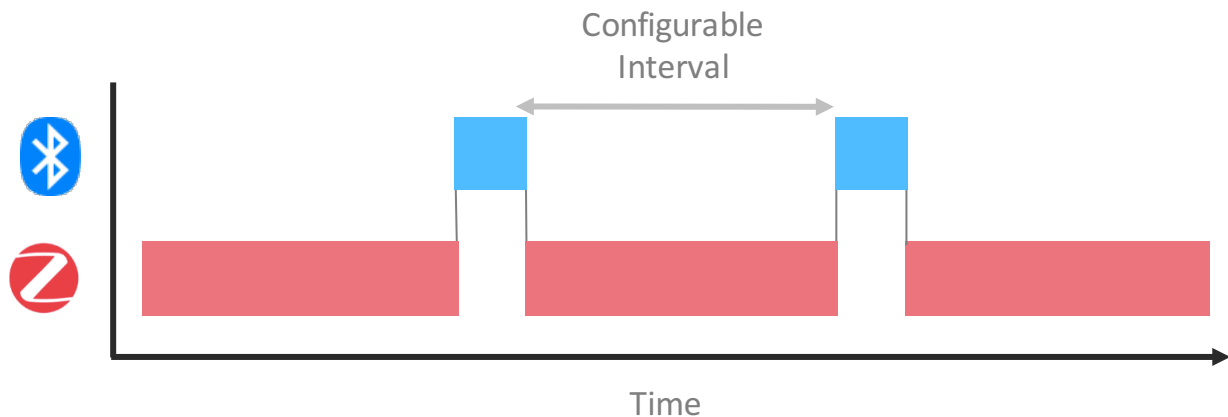


Figure 4: Simultaneously running Zigbee and Bluetooth on a single radio

The Zigbee protocol provides mesh network functionality with short payloads and duty cycles. The protocol is proven and tested, and provides robust performance even with temporary loss of radio. With built-in capability to handle situations where lamps and luminaires are removed from the network, Zigbee can automatically re-route signals and ensure that the network is operative.

Bluetooth requires a more rigid, deterministic timing schedule for fixed connections and reliable beaconing functionality. This makes it possible to combine the two protocols on a multiprotocol SoC. By accepting that each protocol will not have 100 percent access to the SoC resources at all times, Bluetooth will just need to have priority over Zigbee.

Implementing a multiprotocol, single-chip solution involves sharing the hardware and code infrastructure. This requires a real-time OS kernel for sharing of the resources. A radio scheduler provides the correct time-slicing between the protocols, and a radio abstraction layer ensures a consistent radio API for both protocols.

The multiprotocol solution must make it easy to integrate value added services. Lighting manufacturers should be aware of the components of multiprotocol, and ensure that they select a professional grade multiprotocol solution for their products.

Adding Functionality in a Cost Effective Manner

We have established that using multiprotocol enables manufacturers to provide more than one protocol – address markets that have adopted solutions from more than one protocol. With only one hardware solution, new lighting devices can become part of a larger ecosystem compared to a single protocol solution. This is good news for both device makers and users.

A single-chip solution reduces BOM cost as much as 40 percent, and optimizes inventory and simplifies logistics. With a unified hardware platform, it is possible to reduce maintenance and test costs and introduce new designs faster. Using only one design, manufacturers can pick the protocol they need. Differentiation is made possible with a single Zigbee solution, a Bluetooth enabled solution, or in combination, an enhanced mesh and beacon solution. Lighting manufacturers that show value through cost-efficient, scalable and futureproof solutions can enter new markets and face fewer investment barriers.

Being first to market comes with many benefits. When adding connectivity to products like LED lamps and luminaires, and components like drivers and control units, sensors and switches, there are a few options that can help shorten the time to product launch. All of them have benefits and challenges manufacturers need to be aware of.

Conclusion

The solid-state lighting market is shaking up its value chain. Through several phases, LED-based lighting is transformed into to smarter, connected home and commercial applications. A key ingredient enabling this is wireless connectivity. To implement the next level of sustainable and connected lighting, manufacturers need to ensure that they have a robust hardware and software platform as the platform for their lamps and luminaires. Lighting manufacturers are now able to combine multiple protocols such as Bluetooth and Zigbee in a cost-effective manner to deliver additional value by simplifying setup and control and adding location based services for asset tracking and advertising.

<p>Learning Center</p> <p>Multiprotocol wireless connectivity</p> <p>https://www.silabs.com/products/wireless/learning-center/dynamic-multiprotocol.html</p>	<p>Learning Center</p> <p>Bluetooth beacons</p> <p>https://www.silabs.com/products/wireless/learning-center/bluetooth/beacons</p>	<p>Learning Center</p> <p>Bluetooth 5</p> <p>https://www.silabs.com/products/wireless/learning-center/bluetooth/bluetooth-5</p>	<p>Getting Started</p> <p>Multiprotocol kits and software</p> <p>https://www.silabs.com/support/getting-started/multiprotocol/dynamic-multiprotocol.html</p>
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Terminology

Advertisement	Generic Bluetooth advertisement capability
Beaconing	Bluetooth advertisement with using Apple’s iBeacon, Google’s EddyStone or other beacon formats
Bluetooth Mesh	A new mesh networking protocol based on Bluetooth with native mobile device support
Bluetooth LE	Bluetooth with low energy functionality with mobile device support
Lamp	Used by the lighting industry for light bulb
LED	Light-emitting diodes. The light source in lamps and luminaire

Light fixture	See Luminaire
Luminaire	A complete electric light unit (including light source, lamp(s), drivers, parts and wiring)
Mesh beaconing	Bluetooth mesh uses dedicated beacon packets for example to advertise a presence of a Bluetooth mesh network
Multiprotocol	Multiprotocol makes it possible to time-slice multiple wireless protocols on a single SoC
OTA	Over-the-air updates makes it possible to add functionality and update the software on the SoC
SoC	System-on-Chip is an integrated circuit with all components needed for wireless communication
SSL	Solid-state Lighting uses LEDs as a light source
Thread	An open, wireless mesh standard that carries IPv6, used in smart home and lighting applications
Zigbee	A proven, open wireless mesh network standard used in smart cities, home, retail, and lighting