WHITE PAPER

Short range low power wireless devices and Internet of Things (IoT)

White paper

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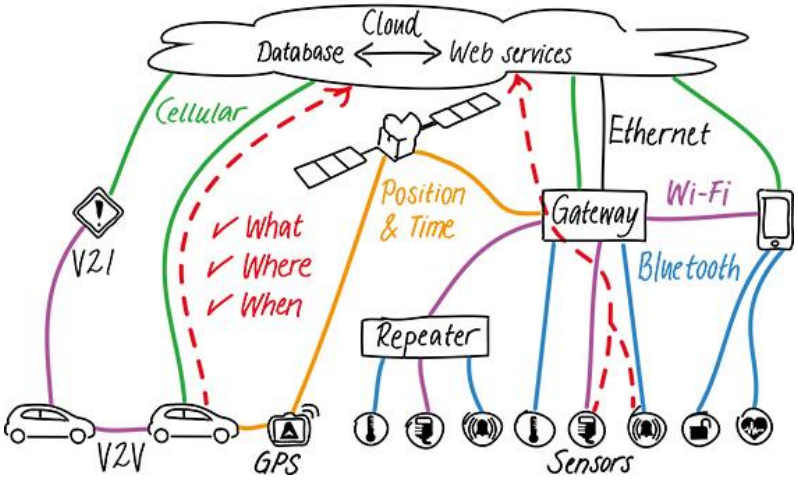
Abstract

This paper discusses the topic of the "last 100 meters connectivity" in systems where small devices (such as various sensors) are connected to services on a wide-area Internet network. Subject matters covered are the requirements on the "last 100 meters connectivity" vision as well as what wireless technologies would be suitable for future Internet of Things (IoT) use cases.

This paper also presents the background to why u-blox envisions the "last 100 meters connectivity" is an important factor in the area of IoT and u-blox' view on the impact of IoT in general.



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1 Background

The Internet of Things (IoT) has been a hot topic for a couple of years now, and many connectivity players predict a large growth within the next ten years.

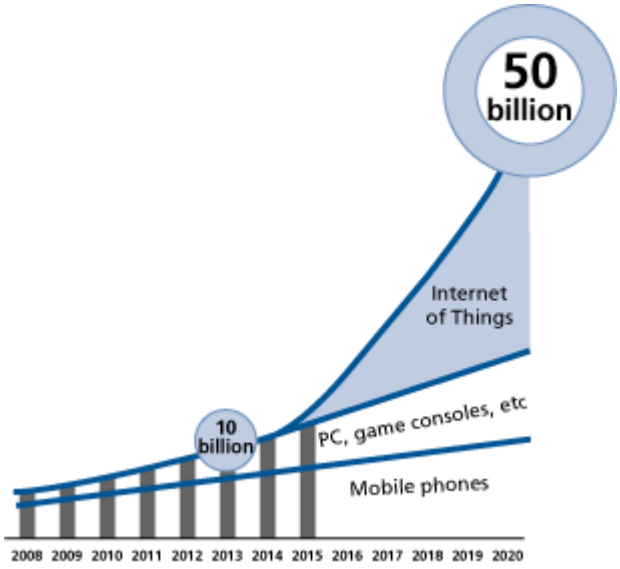

Figure 1: Device distribution in IoT

Figure 1 shows predictions of future connected devices done by the companies Ericsson and Cisco. The graph shows a growth of the personal devices such as phones, tablets, laptops, game consoles; however, this growth is limited by how many people we are on the planet. The real large growth is predicted from all other types of connected small devices in areas like home automation, smart energy, elderly care at home, transportation, asset tracking and many others. The number of these devices is virtually unlimited.

This growth is already underway, but today most of the applications with using devices connected via the Internet are vertical – these closed applications are typically referred to as "silos".

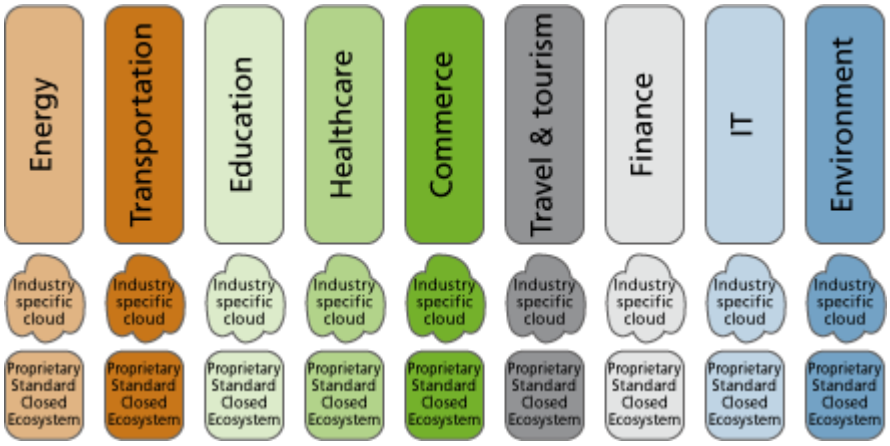

Figure 2: Applications as vertical "silos"

The real impact of IoT will occur when data from the silos are combined to create complete new applications. This evolution will only be possible if the data from all the small devices are made available on the Internet. The data from the small devices combined with the new knowledge emerging in the area of "big data" will create the framework for many new types of applications. This progress will drive the growth of IoT.

The question is how to infuse this progress when there are many different wireless technologies in the IoT atmosphere.

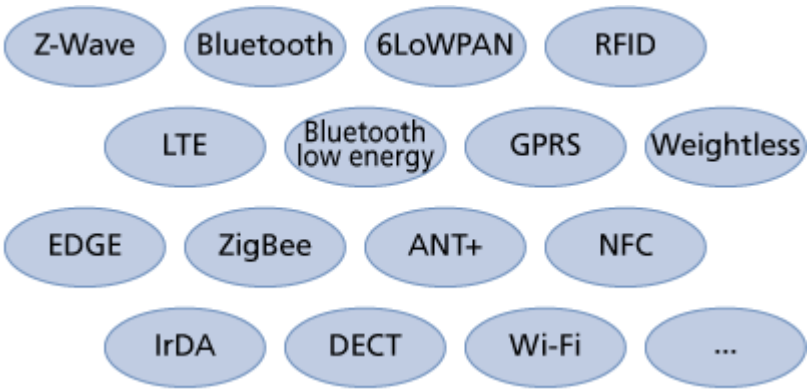

Figure 3: Wireless technologies in the IoT space

Figure 3 lists some IoT related international standards but there are many others (e.g. domain-specific standards within metering such as Wireless M-Bus and more).

2 Focus on the “last 100 meters”

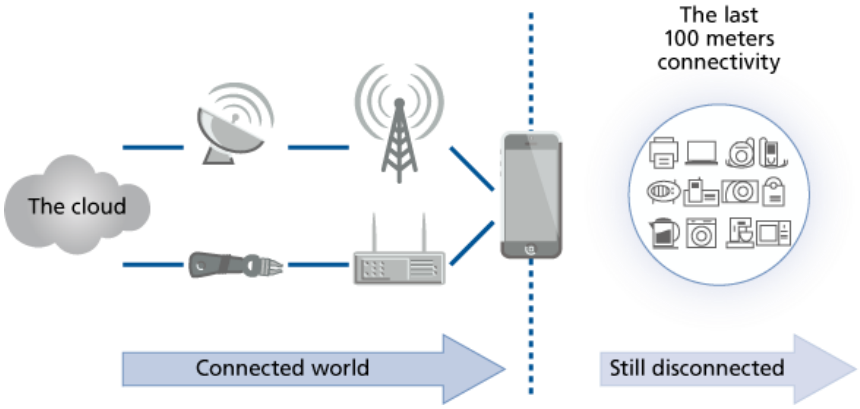

Figure 4: The “last 100 meters”

Today, the devices operating within the “last 100 meters” are typically not connected. The wide-area network is to a large extent connected through smartphones, home routers (e.g. ADSL routers) and GSM/3G/4G routers.

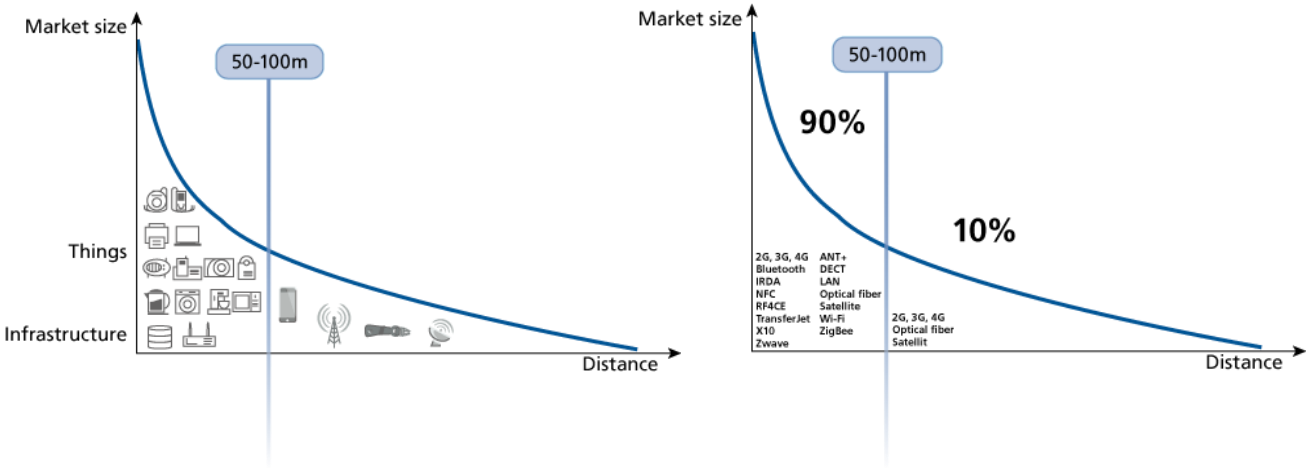

Figure 5: Market size and technologies

The “last 100 meters” presents >90% of the potential, but the ways to achieve the connected vision are extremely diverse. Many different technologies compete in this space including international standards, domain-specific standards (used in one specific vertical) and many proprietary technologies.

3 Requirements of “last 100 meters” technology

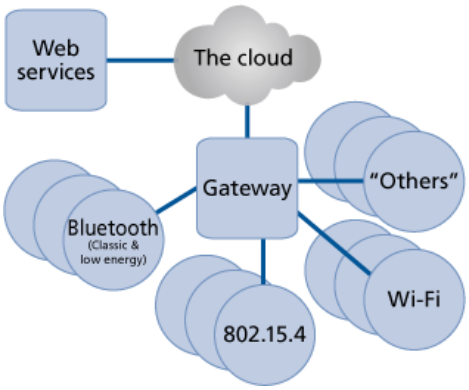

Figure 6: "Last 100 meters" architecture

An architecture with a gateway that serves as an interface between the wide-area network (Internet) and the short range network is required to complete the “last 100 meters” architecture.

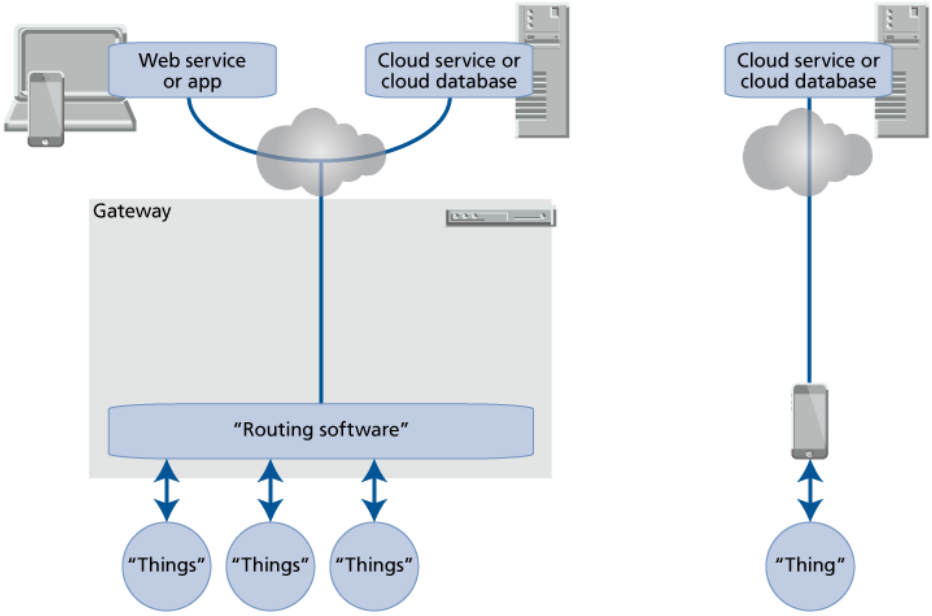

Figure 7: Fixed AND mobile use cases

A required feature of the chosen IoT short range technology is to support mobile use cases where a smartphone or other mobile device can be used as a temporary gateway. There are also some applications where the same IoT device (sensor) is used for both mobile and fixed use cases (see figure 7).

Important drivers when selecting the appropriate short range wireless technology for IoT use cases include the following:

- **Cost** of the radio technology. As many of the devices (sensors) are small low-cost devices, the IoT chosen radio technology must not add too much additional cost to the bill-of-material (BOM). This also implies that the radio and device application in many cases need to share the same computing engine (microcontroller / MCU).
- **Power consumption**. Many use cases require a battery or some kind of energy harvesting technology as a power source.
- **Ease-of-use**. It must be easy to associate a device to the network and to the Internet service.

- **Security**. Security (authentication and encryption) features must be adequately supported by the wireless technology and sometimes end-to-end security (all the way from sensors to the Web services) is required.
- Available **ecosystem**. The possibility to connect to smartphones, tablets, PCs, home gateways, etc. is important. This requirement also drives up volumes and has an important impact on the cost; a good example is in Classic Bluetooth where the large volumes of manufactured phones and phone accessories have lowered the costs of the technology.
- **Range**. We need the capability to cover an enough range or have some extension capabilities to increase the coverage (repeaters, routers, etc.) without largely affecting the system cost.
- An **international wireless standard** that is not domain-specific. Domain-specific standards will still be widely used, but for most IoT purposes a basic wireless technology that fits many verticals is essential for successful adoption.

4 Which wireless technologies should one choose?

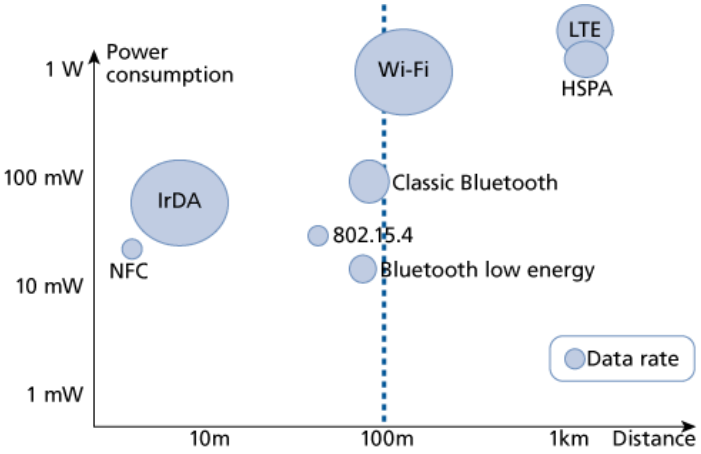

Figure 8: Short range technologies with power consumption, distance and data rates

Figure 8 shows a graphic representation of the short range technologies that best accommodate the drivers and requirements listed in section three.

This graph mainly shows technologies that are available in mobile devices such as smartphones, laptops, etc. The reason for only showing wireless technologies available in mobile devices is the above mentioned requirement on a largely available ecosystem. One exception to the rule is 802.15.4 (including standards and protocols such as ZigBee, WirlessHART, Thread and others), which both fulfills the requirement on an internationally used standard and is widely used in early IoT use cases primarily for building automation and smart energy applications.

The illustrated range is point-to-point and heavily depends on the individual devices' radio design and shall thus be considered as an indication only. The same concept applies for power consumption since the actual power consumption is use case dependent. Our illustration should be viewed as an indication of how well the different technologies support low power applications.

As we are focusing on the "last 100 meters" connectivity, we will look more into the wireless technologies situated to the left of the blue dotted line.

	Bluetooth low energy	802.15.4	Wi-Fi	NFC	iRDA
Remote control	✓	✓	✓	×	✓
Security	✓	✓	✓	✓	×
Health and fitness	✓	✓	✓	×	×
Home and building	✓	✓	✓	×	×
Industrial	✓	✓	✓	×	×
Positioning	✓	✓	✓	×	×
Payment	✓	×	×	✓	×
Automotive	✓	×	✓	✓	×
Comments	Largest ecosystem (phones, tablets, etc.). Low power.	Low power but closed ecosystem. Well-established in specific use cases e.g. smart energy.	Large ecosystem but high power consumption. Infrastructure connectivity is a bonus.	Low power but very short range.	Needs line of sight.

Figure 9: Technologies and verticals

Figure 9 shows a table with different wireless technologies in specific verticals according to u-blox. Infrared and NFC can be ruled out except for very specific use cases / verticals. u-blox believes that 802.15.4-based technologies will become a niche technology area, especially where it is already established, such as in home and building automation and smart energy (see more on this in the conclusions section later).

Let us compare the three selected technologies seen from the drivers (requirements) identified earlier:

	Bluetooth low energy	802.15.4	Wi-Fi
Cost	✓	✓(✓)	✓
Security	✓	✓	✓
Power consumption	✓	✓	×
Ecosystem	✓	×	✓
Reliability	✓	✓	✓
Ease of use	✓	✓	✓
Range	✓	✓(✓)	✓

Figure 10: Comparison of wireless technologies and their usefulness in IoT

Conclusions that can be drawn from the figure 10 table include the following:

- All three technologies have built-in link layer authentication and encryption, which sometimes needs to be completed with end-to-end security from the sensor to the Web application.

- Some IoT use cases may exist fully behind an enterprise firewall (e.g. a use case inside a factory where the IoT Internet Service runs on a local server). There are also IoT systems operating on a wide-area network but acting as local networks by using VPN tunnels or similar security mechanisms.
- Correctly used, Bluetooth low energy has the potential for less power consumption than 802.15.4 (less overhead).
- The lack of native support for 802.15.4 in mobile devices (smartphones, tablets, laptops, etc.) that play such a great importance to the IoT ecosystem, is a problem especially for mobile or temporarily mobile use cases.
- The ecosystem with phones, tablets, laptops and phone accessories will drive down the cost for Bluetooth low energy.
- 802.15.4 has a main advantage in its range extension capability since many 802.15.4 based technologies (e.g. ZigBee) support "mesh" whereby coverage can be extended via routers. There is work underway to add mesh functionality in Bluetooth low energy as well.
- Bluetooth low energy is very reliable with its support for Adaptive Frequency Hopping (AFH) and other features inherited from Classic Bluetooth.
- Wi-Fi can be used in devices with less demand on low power consumption and as a wireless backbone in combination with other technologies (more on this later).

The u-blox conclusion is that Bluetooth low energy has a high potential in becoming an important technology for the "last 100 meters" in low power, low cost, small devices. However, there will still be use cases where 802.15.4-based technologies are used especially in areas where it is already established. In spite of its installed base in smart energy, home and building automation applications, u-blox envisions that 802.15.4 will face competition in Bluetooth low energy in these applications as well. Wi-Fi will be used in devices where cost and low power is less important and as a wireless backbone combined with the other wireless technologies.

5 The importance of gateways in IoT

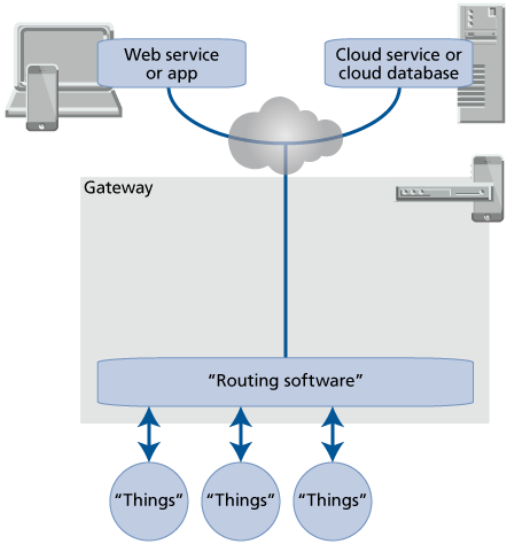

Figure 11: IoT architecture for short range sensors / devices

Gateways are a requirement when connecting small low-power short range devices. Sometimes the gateways are fixed devices connected to a backbone network and sometimes they are embedded within other devices e.g. in an Internet router (ADSL or GSM/3G/4G routers or similar).

A mobile device can also act as a gateway and there are several use cases where this use can be applicable. For example, one use case is when the sensor / device is carried together with the phone e.g. a body-worn sensor. Another use case is where the smartphone becomes a temporary gateway when it approaches the sensor / device (e.g. an access control system where the phone is used to authenticate the access to Internet services).

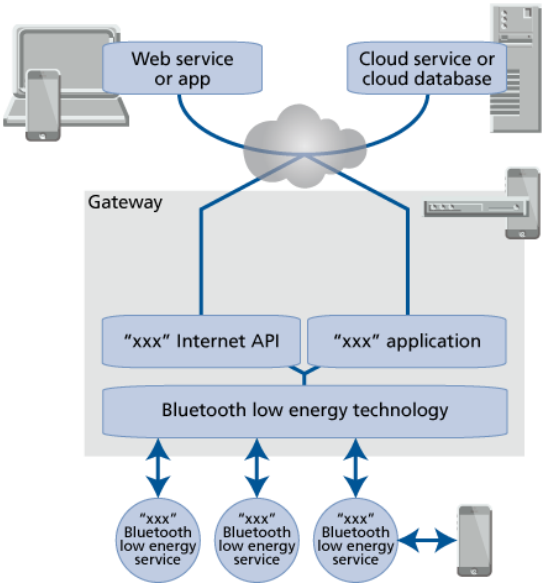

Figure 12: Traditional Bluetooth low energy use case

Figure 12 shows a use case where the traditional Bluetooth low energy concept of characteristics and services are exposed from the sensors / devices. This use case will typically require knowledge on behalf of the gateway

on what services the sensors expose. Typically, the gateway will expose this knowledge as an Internet accessible API or by pushing data read from the sensors to an Internet based service.

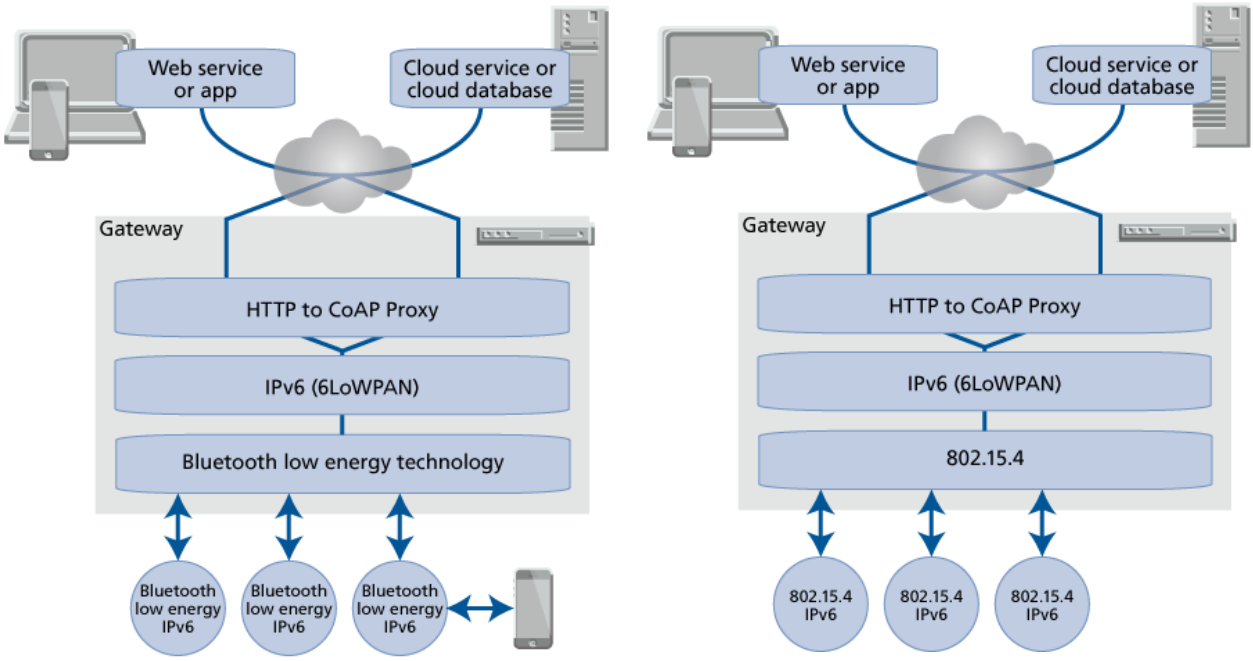

Figure 13: IPv6 "all-the-way" and IoT

Figure 13 shows Bluetooth low energy and 802.15.4 used as transport for IPv6 based communication "end-to-end". In this use case, an IP-based application in the sensor / device is transparently connected to an Internet service. This case typically uses compression technologies such as 6LoWPAN and CoAP, to enable an efficient use of the limited resources of a Bluetooth low energy or an 802.15.4 network. This use case may also enable "end-to-end" security although this will require more computing power in the sensor / device.

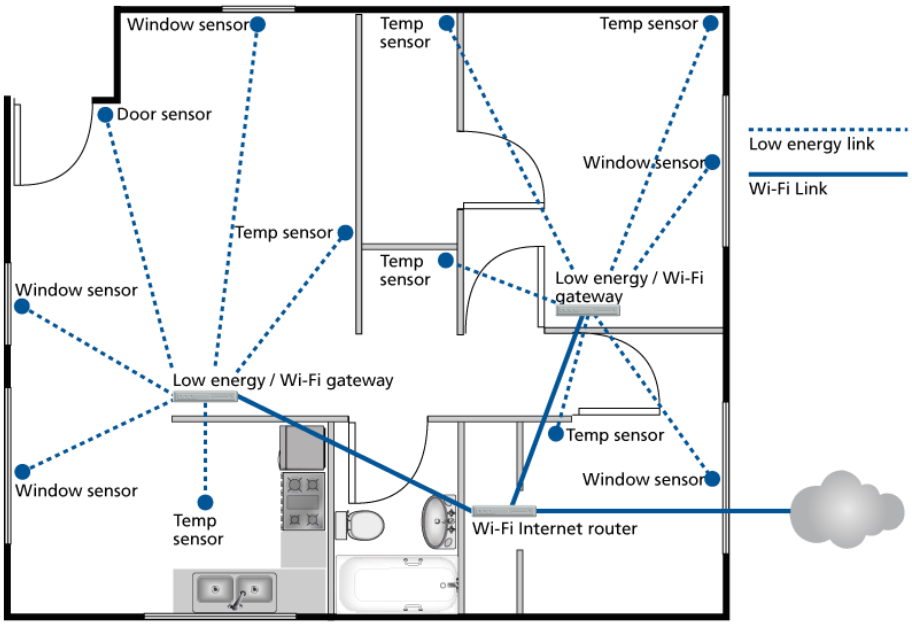

Figure 14: Use Wi-Fi "mini gateways" to extend coverage and system size

Figure 14 shows the use of Wi-Fi serving as an intermediate backbone connecting islands of sensors / devices. This makes use of the multiradio capability of the short range radio chips already available e.g. chipsets supporting simultaneous use of Bluetooth low energy and Wi-Fi to create miniature gateways. The gateways communicate via Bluetooth low energy down-stream and Wi-Fi up-stream. The Wi-Fi up-stream link is connected to a Wi-Fi router connected further upwards to Internet services. This scenario may be used to extend the range or the system size.

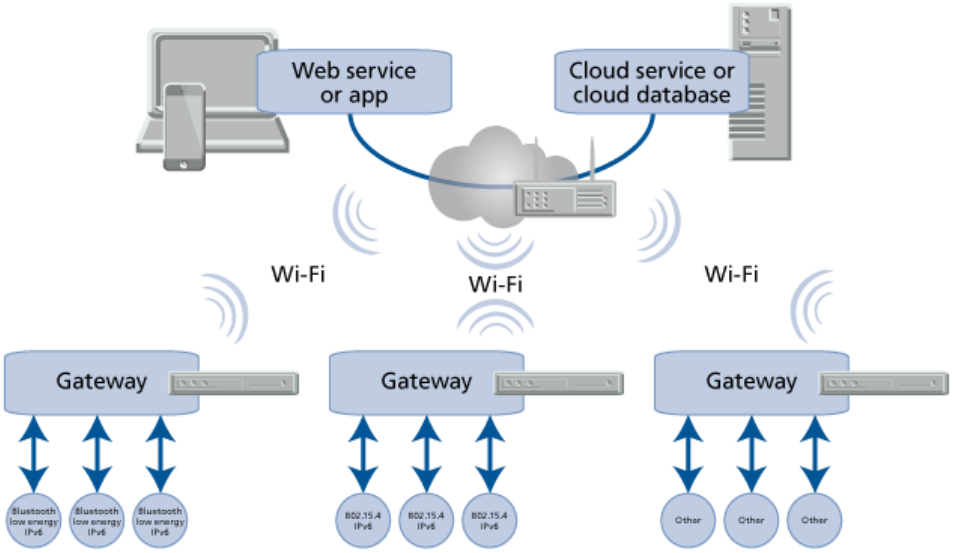

Figure 15: Interconnecting multiple technologies.

Figure 15 shows the use of gateways to create a system with interconnecting multiple technologies. The gateways are used to perform the necessary translation to a common backbone (e.g. an IPv6 backbone). This use is especially interesting and easy to use when interconnecting technologies via IPv6 "all-the-way," as described in Figure 13.

6 Summary

The following are the conclusions one can make from this paper:

- There is huge potential for "last 100 meters" of "things". The main part of future growth in wireless Internet connectivity indeed stems from this area.
- Security and privacy, both for private enterprise level IoT use cases and public use cases are essential and need to be individually investigated for each specific use case.
- Low power, short range radio technologies like Bluetooth low energy, 802.15.4 are often a requirement to enable these use cases and various gateways are needed to connect all these low-power devices to the Internet.
- Some of the gateways will be fixed devices connected to the Internet but for some use cases there is a need for smartphones or other portable devices to serve as mobile gateways.
- There will be several short range low power radios used in parallel but Bluetooth low energy is a rising star that u-blox believes will likely take a significant portion of this market.

About the author

Mats Andersson is the Senior Director Technology in the Product Center Short Range Radio of u-blox. Just prior, he was the CTO for connectBlue for almost 15 years. Mats Andersson has more than 10 years of experience in wireless and more than 30 years of experience in the field of industrial automation. This includes managing development of industrial automation products at Alfa Laval Automation and ABB Automation Products.

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Swiss u-blox (SIX:UBXN) is a global leader in positioning and wireless semiconductors and modules for the automotive, industrial and consumer markets. Our solutions enable people, vehicles and machines to locate their exact position and communicate wirelessly over cellular and short range networks. With a broad portfolio of chips, modules and software solutions, u-blox is uniquely positioned to empower OEMs to develop innovative solutions for the Internet of Things, quickly and cost-effectively. With headquarters in Thalwil, Switzerland, u-blox is globally present with offices in Europe, Asia and the USA. www.u-blox.com

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