Low Power Wireless Communication for the IoT

Nadee Seneviratne

According to the Internet Society, we can to have 100 billion connected IoT devices with a global market value of more than $11 trillion by 2025. The IoT, which strives to utilize the advancements in computational power, miniaturization of electronics, and network interconnections to create newer capabilities, will have a strong transformation in the way we live. This article introduces several wireless technologies that enable the IoT.

One of the key challenges of IoT is the requirement of low power wireless communication with the connected devices. Through this article, the reader will be able to understand the need for low power wireless communications and the related emerging wireless technologies to satisfy this need. It will also discuss the suitability of these technologies in various scenarios using several case studies.

Why low power wireless communication?

The range of applications proposed for the IoT is impressive. While it is obvious that to enable all these applications ranging from smart cities to personal health, wireless connectivity among the objects are needed, a common attribute for all is the limited power available in the devices to maintain their functions. Most of the sensing devices run on battery power and thus, the ultimate objective would be to maintain a longer battery life, preferably the life time of the device. Also, the available power should be consumed optimally. Therefore, it is necessary that, communication protocols being deployed in these networks operate under low power and with efficient energy consumption.

There are a number of emerging connectivity technologies that are promising for deployment in IoT networks. Yet, careful consideration should be paid to the context of the application. Low power wireless communication standards are emerging day by day to support the varying range of requirements for the IoT, in terms of security, data rate, and transmission distance requirements. Energy harvesting is another option being looked at in IoT applications to further optimize energy utilization in devices.

Low Power Wireless Communication Technologies

A network's range is typically categorized into four classes as Personal Area Network(PAN), Local Area Network (LAN), Neighborhood Area Network (NAN) and Wide Area Network (WAN). PANs usually cover a range of 10m whereas, LANs could go up to a range of 100m. NANs can reach a range over 25km and as the name implies, WANs spread across a very large area as big as the entire globe. Wireless communication protocols are available to cater to the demands of all these types of networks.

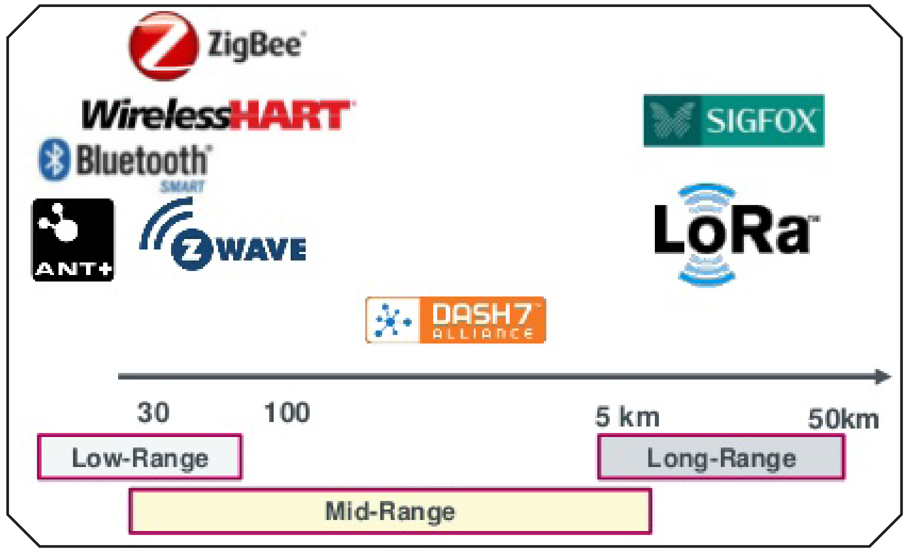
Among the most commonly heard wireless connectivity protocols is the Wi-Fi technology (for LANs), developed based on the IEEE 802.11 standard. Wi-Fi standards are so prevalent around the globe due to its favorable features like mostly operating in the ubiquitous unlicensed frequency band of 2.4 GHz, strong indoor coverage helping homes and enterprises connect a number of devices wirelessly, and the typical data rates of 150-200 Mbps. However, these benefits come at the cost of high power consumption. Wi-Fi may not be the feasible solution to operate a battery powered device in an IoT application. On a positive note, several silicon devices are being developed now to integrate Wi-Fi

into IoT applications with limited power consumption (e.g.: Texas Instrument's CC3200)
The following technologies are popular low power wireless communication protocols and thus are ideal candidates to be deployed in suitable IoT scenarios.

Bluetooth Low Energy (BLE)

BLE, also known as Bluetooth Smart, is the latest addition to the classic Bluetooth standard which has been available since 1994. This is specifically designed to cater to the demand of low power wireless connectivity among IoT devices. Bluetooth is a short range wireless communication standard. The conventional usage of Bluetooth includes tasks such as audio or data streaming, where a large amount of data is transmitted and frequent communication happens between the two connected devices. BLE helps to expand its applications in short range communications where it can now be deployed in power constrained devices such as wireless sensors and controls which on the other hand transmit small amounts of data and communicate infrequently (Eg: Wearable health tracking devices).

Life time of a low power device is increased by BLE via 3 mechanisms. It uses a simple device discovery method, maintain power efficient peak, average and idle modes and ensures reliable transmission of data. BLE supports



only 40 channels compared to 79 in Bluetooth Classic, which results in significant reduction time in connection set up. Out of the 40 channels of BLE, 3 are advertising channels which helps to discover devices and establish the initial communication between the devices. Robustness of the advertising channels are maintained by selecting the channels which have the least amount of interference from Wi-Fi channels. As a result, BLE has to be switched on for just 0.6 to 1.2ms to scan for other devices. BLE generally uses a client/server model where in order to connect the devices, when the client receives an advertisement packet, it sends a connect request to the server. Once the advertiser receives that, the devices will be connected enabling data exchange.

BLE uses a modulation technique which has low power consumption. Data channels can perform bidirectional communication between the connected . BLE can cover a range of about 150m (open field). As BLE is specifically designed to small amounts of data from time to time, unlike Classic Bluetooth, BLE remains in sleep mode until a connection is initiated.

The actual connection times of BLE is said to be very low around 3ms, whereas for Classic Bluetooth it can take up to around 100ms. BLE maintains a lower packet overhead which also contributes to lower power consumption.

Internet Protocol (IP) support was added to Bluetooth Smart in its latest version, allowing BLE sensors to access the internet directly via 6LoWPAN connectivity (described later). As a result, existing IP infrastructure could be used to manage Bluetooth Smart 'edge' devices.

Some applications suitable for BLE include blood pressure monitors, wearable activity and performance trackers (e.g. Fitbit), industrial monitoring sensors, geography-based, targeted promotions (iBeacon), and Public transportation applications. A major strength of BLE is that it is supported by smartphones.

ZigBee

The specialty of ZigBee, which is implemented based on the IEEE 802.15.4 standard, is that it can work in a mesh network configuration. In a mesh, data can 'hop' from one device to another throughout a large scale network until it reaches the destination. ZigBee is known to be a low-throughput, low-power and low-cost technology which operates in the 2.4 GHz ISM band. It is most commonly used for personal or home area networks and also in a wireless mesh for networks that operate over longer ranges. According to specifications, ZigBee can deliver a throughput of 250 kbps, yet typical usage is at lower data rates. ZigBee's ability to maintain very long sleep intervals and low operation duty cycles benefit the IoT devices to be powered by coin cell batteries for years. The technological enhancement to ZigBee standards are now enabling even energy harvesting techniques for battery-less operations. The coverage range of ZigBee could be from 10m to 100m.

ZigBee Remote Control (RF4CE) profile is said to provide several advantages to complex designs as a result of its favorable features such as low-power operation, high security, robustness and high scalability with high node counts. In fact, it is said that any device in a ZigBee network can connect to a maximum of 254 devices where the size of the entire network could be up to 655535 nodes. These features have paved the way to make ZigBee a popular candidate for applications such as smart energy, home automation and in lighting control applications. As ZigBee is not supported in mobile phones, and cannot easily communicate with IoT protocols, it requires an application-level gateway connect to with TCP/IP networks.

IPv6 over Low power Wireless Personal Area Networks (6LoWPAN)

This standard has utilized the larger addressing space of IPV6 which offers approximately 5 x 1028 addresses so that even the smallest devices with limited processing ability can transmit information wirelessly using an internet protocol. Also, a 6LoWPAN device can communicate with any other IP based device on the internet including Ethernet and Wi-Fi. Another reason to use IPV6 over IPV4 is its capability of built-in support for network auto configuration.

Created by the 6LoWPAN working group of the Internet Engineering Task Force, this was formalized in 2011. 6LowPAN is an open network protocol (similar to HTTP, UDP and TCP etc.) that allow IPv6 packets to be sent and received over IEEE 802.15.4 based networks. Utilizing the advantages of 802.15.4 such as mesh network topology, large network size, reliable communication and low power consumption along with the added benefits of IP communication, 6LowpAN is well suited for the designs with Internet-connected sensors and other low data throughput and battery-operated applications.

LoRaWAN

As the acronym 'LoRaWAN' is derived from the term 'Long Range', it implies that it caters to a crucial concern in the context of IoT which is enabling communications over long ranges at very low power levels. LoRaWAN™ specification comes under low power wide area network (LPWAN) category, which makes it ideal to be used for battery operated wireless devices in regional, national or global levels. While the range of LoRaWAN in urban areas will be 2-5km, in suburban areas it can be extended up to a distance of 15km. The network architecture of LoRaWAN is a star-of-stars topology where gateways act like bridges which relay data between end devices and a central server. Gateways and central network server is connected via IP connections whereas end devices perform single hop wireless communication to one or many gateways.

Different frequency channels and data rates are there for communication between end devices and gateways. The selection of the proper data rate is based on the compromise of message duration and the communication range. Data rate of LoRaWAN varies from 0.3kbps to 50kbps.

Technology (IEEE standard)	ZigBee 802.15.4	Bluetooth 802.15.1	Wi-Fi 802.11a/b/g/n	UWB 802.15.3
RF frequency	868/ 915 MHz, 2.4 GHz	2.4 GHz	5.8 GHz-a 2.4 GHz- b/g/n,	3.1 to 10.6 GHz
Data rate (Mb/s)	0.25	1~3	11~105	110~1600
Range (m)	10~100	10	10~100	4~20
Useful BW (MHz)	0.6	1~3	20-40	120~1000
Power consumption	Very low	Low	High	Low
Advantages	Power, Cost	Cost, Convenience	Speed, Flexibility	Data capacity

The battery life of end devices and the network capacity is optimized by means of an Adaptive Data Rate (ADR) scheme, in which the network server manages the data rate and RF output for each end device individually.

With low power and long range capabilities along with the ability to connect millions of devices, LoRaWAN is a promising technology to be applied for various IoT applications. Very few proposed examples are, smart metering, inventory tracking, vending machine data and monitoring, automotive industry, and utility applications.

Among the pioneering technologies being developed upon the base of LoRaWAN is the Symphony Link by Link Labs which currently supports up to 250,000 end points.

Z-wave

A strong competitor to ZigBee, Z-Wave is another RF communications technology designed specifically for control, monitoring and status reading applications in residential and light commercial environments. Z-Wave can support full mesh networks. As it operates on the sub-1GHz band, it is less vulnerable to interference from wireless technologies operating the ubiquitous band of 2.4 GHz (Wi-Fi, Bluetooth, and Zigbee etc.). Z-Wave supports data rates up to 100 kbps and is optimized for reliable and low-latency transmission of small data packets. The typical range covered by this protocol is about 30m while it is highly scalable to enable control of up to 232 devices.

Summary

This article discussed five wireless technologies considered to be prime candidates for the IoT in different situations. All have low power communication as a basic feature, while each has its own additional strengths as summarized below.

• Bluetooth Low Energy (BLE) has the strength that it is supported by all modern smartphones. Hence IoT devices have a convenient gateway to the Internet through smartphones.

• The strength of Zigbee lies in its support for mesh networking. Multi-hop networks can be implemented covering a long range, with each node supporting only short range communications.
• 6LowPAN has the advantages of addressing a huge number of devices through IPv6, and being able to directly communicate over the Internet without the need for a gateway.
• LoRa's special strength is long distance communication at low power.
• Z-wave has a large commercial device base, and operates outside the 2.4 GHz ISM band, thus avoiding interference from a multitude of applications operating in this band.

Nadee Seneviratne
Lecturer
Department of Electronic and Telecommunication Engineering
University of Moratuwa
0716261687