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A Survey on Bluetooth Low Energy: A Low Power Wireless Transmission Technology

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***Abstract*—In recent years, the Internet of Things (IoT) has attracted much attention because of the provided functionalities that can advance humanity in terms of intellect, automation, convenience, etc. Bluetooth Low Energy (BLE) is a significant protocol for IoT applications. Small, compact, sophisticated and embedded sensors are a pervasive technology in everyday life for a wide number of applications like wearable devices, healthcare, fitness, beacons, security, domotics, e-health systems etc. In this context, a wireless transmission protocol plays a key role, and among available solutions, BLE is gaining more and more popularity. BLE integrates different features like good performance, low-energy consumption, high data transfer speed etc. The aim of this work is to review the overview of BLE, and their usages in our daily life. However, this manuscript will give good comprehension for the new researchers, who want to do research in this field of BLE and facilitate knowledge accumulation in efficiently.**

***Index Terms*— Bluetooth Low Energy, Communication, IoT, Wireless transmission.**

I. Introduction

BLE is a new open, short range radio technology developed by Special Interest Group (SIG). BLE has been designed as a low- power solution for control and monitoring applications. BLE is the distinctive feature of the Bluetooth 4.0 specification. BLE is one of the new technologies feeding this emerging market. It provides the tools and abilities to design and implement environmental friendly and low-cost applications which can operate and communicate in mobile environments, in the optimal case using only a single chip. It is resistant to interferences from other radio signals and can go through other objects, along with its support for encrypted data packages it is more meaningful extension to the Bluetooth standard [1].

BLE inherits a majority of design of classic Bluetooth in terms of protocol stack, data structure and working band. BLE operates on 2.4GHz ISM band using 40 channels, each with a width of 2MHz. Among those channels, three channels (ch37, ch38, ch39) are defined for broadcasting purposes such as device advertising. Other 37 channels are responsible for data transmission. To attenuate interference in such a crowded Industrial, Scientific, and Medical(ISM) band, BLE inherits frequency hopping mechanism in both advertising and data channels. While classical Bluetooth has 79 channels, each with a width of 1MHz. In contrast to classical Bluetooth, BLE stays on each channel for a longer time, making the timing requirements much more relaxed due to its longer stay in each channel. In addition, a more concise state machine is devised to simplify the device discovery and facilitate power saving. Although the communication mechanism is well defined by the BLE standard [1].

A. History of BLE

In 2001, researchers at Nokia began developing a wireless technology adapted from the Bluetooth standard which would provide lower power usage and cost, the results were published in 2004 using the name Bluetooth Low End Extension.

After further development with partners in particular Logitech and within EU FP6 project MIMOSA, actively promoted and supported also by STMicroelectronics since its early stage, technology was released to the public in October 2006 with the brand name Wibree. Wibree, also called "Baby Bluetooth", is a low-power wireless local area network (WLAN) technology for small, button cell battery-powered devices, such as watches, wireless keyboards, and gaming and sports sensors.

In June 2007 an agreement was reached with Bluetooth SIG members to include Wibree in future Bluetooth specification as a Bluetooth ultra-low-power technology, known as Bluetooth Low Energy technology.

Fig. 1. BLE

Integration of BLE with version 4.0 of the core specifications was completed in early 2010. The first smart phone to implement the 4.0 specification was the iPhone 4S, released in October 2011. A number of other manufacturers released BLE ready devices in 2012. The Bluetooth SIG officially presented Bluetooth 5 on June 16, 2016, in London and one important

change on the marketing side is that they discard the point number, so it now just called Bluetooth 5 and not Bluetooth 5.0 or 5.0 LE like for Bluetooth 4.0. Bluetooth 5 will quadruple the range and double the speeds compared to Bluetooth 4.x, and provide an eight-fold increase in data broadcasting capacity.

On July 18, 2017, the Bluetooth SIG released Mesh Profile and Mesh Model specifications officially. Mesh specification enables using BLE for many-to-many device communications for home automation, sensor networks and other applications.

B. Building Blocks of BLE

The architecture of BLE is divided into three important layers [2]. These layers or blocks are called building blocks of BLE. The layers are,

- Application
- Host
- Controller

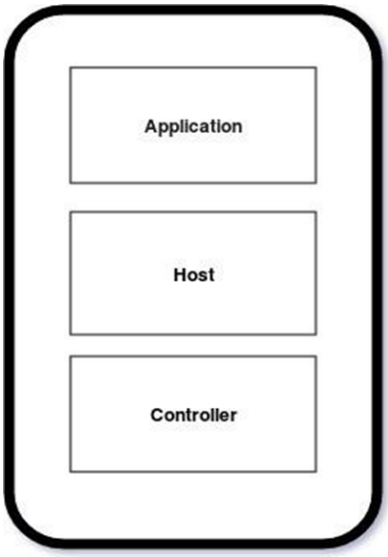

Fig. 2. Building blocks of BLE

Application: Application block is the user application which interfaces with the Bluetooth protocol stack.

Host: The host covers the upper layers of the Bluetooth protocol stack.

Controller: The Controller covers the lower layers. The Host can communicate with the BLE module with the host controller interface (HCI). The purpose of HCI is to interface the Controller with the Host. HCI layer is a thin layer which transports commands and events between the host and controller.

BLE technology places a significant amount of intelligence in the controller, which allows the host to sleep for longer periods of time and be woken up by the controller only when the host needs to perform some action. This allows for the greatest current savings since the host generally consumes more power than the controller.

This paper mainly focuses on surveying of various applications implemented by using BLE and its features. The rest of the paper is organized as follows. Section II describes the Literature survey. Section III presents the BLE features. Finally, Section IV presents the conclusion.

II. Literature Survey

In 2012, Elke Mackensen et al. [3] have proposed performance analysis of BLE sensor system. In this paper the performance analysis results of a BLE sensor system which is based on the Texas Instruments (TI) transceiver will be presented. The results state clearly that BLE is a very interesting wireless technology for wireless sensor systems especially for wireless sensor system powered through energy harvester. The major facts of BLE are low power consumption, a good data throughput and small software stack. For future important investigations these results can be taken as basis. They will help to calculate the lifetime and compute new BLE simulation models.

In 2013, Xia Kun et al. [4] have introduced design of a vehicle control system based on BLE smart phone platform. The system embedded Bluetooth 4.0 achieves the purpose that user can use iphone4s to complete the operation of starting the car and the acquisition of vehicle information without key. The system has the advantage of the low power consumption and can be used in many applications in short-range communication.

In 2014, Ting Zhang et al. [5] uses BLE for wearable sensor-based healthcare systems. Sensor technologies, low power communication modules, and intelligent mobile devices make it possible for healthcare systems to be light weight, modest and usable without location constrains. This paper includes various commercial available wearable healthcare devices with BLE and provides an overview of the methods of development including hardware and software design. BLE technology in wearable healthcare systems is crucial in compressing the device volume and prolongs the battery life

In 2015, Mario Collotta et al. [6] demonstrated a fuzzy-based solution for smart energy management in a home automation wireless network. BLE improves a home energy management scheme by addressing the power load of standby appliances and their loads in different hours of the day. Since the consumer is involved in the choice of switching on/off of home appliances. The fuzzy-based solution manages the consumer feedbacks also.

In 2016, Ankush A. Kalbandhe et al. [7] created indoor positioning system using BLE, this paper explores the BLE technology and provides an alternative to traditional technology used for positioning, such as Wi-Fi or GPS. The technology is most useful in localized settings, where scalability and portability are important. The proposed framework is an indoor positioning utilizing BLE tags which build up connection and measures distances based on elative Received Signal Strength Indication (RSSI) values and similarly shows targeted BLE tags data. The smart phone IPSAPP permits us to make estimations of BLE tags which users can get the location determination

based on parameters such as RSSI and transmitting power value. The accuracy of distance estimation is approximately up to 4 meters in range which shows notification of description of distance location such as Immediate, near and Far depends on range of meter. Hence, positioning is using BLE tags will be more accurate than Wi-Fi and trilateration localization advancements.

In 2017, Jose A. Afonso et al. [8] have introduced IoT system for anytime/anywhere monitoring and control of vehicles parameters. IoT and BLE system designed to allow the monitoring and control of parameters of the users' vehicles anytime and anywhere in the world, through the internet. Residential WSNs in the proposed IoT architecture allows to collecting sensor data and automatic control of the electric vehicle battery charging process.

In 2017, Amit Rander [9] proposed design and development of the android based BLE mobile gateway, in this IoT device low power usages like BLE with the help of low powered BLE devices the sensor data like temperature, body temperature, humidity, accelerometer and magnetometer gets fed in the cloud with a help of standalone android application connected to the internet. A typical architectural approach that can be used for designing a wearable that communicates with the cloud. Tracking wearable's have many features for following and reporting on individual activities generally by using communication with a smart phone or tablet-type device to display status and report data.

III. BLE Features

BLE has a number of unique features that set it apart from other available wireless transmission technologies.

Range: BLE technology offers a somewhat improved range with respect to classic Bluetooth theoretically, up to 200 feet and beyond. However, the technology is still suited for mainly small-range applications.

Latency: BLE is optimized for sending small pieces of information with minimal delay (latency). The total time of sending data is generally less than 6 ms, and as low as 3 ms (compared to 100 ms with classic Bluetooth). This enables an application to form a connection and send data for a short communication burst before quickly tearing down the connection.

Data Rates: BLE is most efficient for transferring very small quantities of data. The technology supports very short data packets (8 octet minimum up to 27 octets maximum) that are transferred at 1 Mbps. All connections use advanced sniff sub-rating to achieve ultra-low duty cycles. These and more features make BLE a great option for applications where the maximum bit rate is of just a few hundred bits-per-second, or less.

Interoperability: To be successful, any wireless technology must ensure that all devices implementing it can communicate with each other. To ensure that BLE devices can communicate with all other BLE devices, the Bluetooth SIG builds into the definition of the technology strong qualification and interoperability testing processes. Moreover, since BLE operates in the open, license free 2.4 GHz frequency band, manufacturers and users of Bluetooth v4.0 devices can count on these devices to interoperate in world wide applications.

Robustness: BLE uses fast, frequency hopping to secure a robust transmission even in the presence of other wireless technologies. This feature makes it very suitable for the various applications, where multiple devices using different protocols, such as Wi-Fi, use the same 2.4 GHz spectrum in a confined space. In addition, adaptive hopping and Wi-Fi/Bluetooth coexistence schemes enable it to be used in a compact device alongside a Wi-Fi radio.

Simplicity: The key characteristic of BLE is its simplicity. Due to this simplicity, devices with built-in single -mode BLE can be made equal to the size of the coin cells that power them, and only a few millimeters thicker.

Low Cost: BLE allows manufacturers to design tiny, single-mode devices with low production costs. In addition, since BLE's architecture shares much of classic Bluetooth technology, adding BLE to a Bluetooth chip to create a dual-mode device involves a minimal cost-add.

The main features of BLE are shown in table.

TABLE I
BLE Features

Specification/Feature	BLE support
Range	Typically 5-10 m, 150 meters can be achieved in open field (implementation specific)
Output power	10 mW (10dBm)
Max. current	15mA (implementation specific)
Latency	3 ms
Data rate(Throughput)	1 Mbps
Topology	Star
Connections	>2 billion
Modulation	GFSK at 2.4 GHz
Robustness	Adaptive frequency hopping, 24 bit CRC
Security	28 bit AES
Sleep current	Approx.1µA (Implementation specific)
Modes	Broadcast, connection, event data models, reads, writes
RF Band	2400 MHz
Active Slaves	Not defined; Implementation dependent
Service discovery	Yes
Profile concept	Yes

IV. Conclusion

BLE emerges as a strong low power wireless technology for single hop communication use cases, which may contribute to connecting a dramatically large amount of new devices to the IoT. To make IoT applications reasonable and ubiquitous, one of the most important considerations is the low power consumption of IoT devices, so they can last a long time without replacing batteries. There is a significant increase in the applications of BLE in different areas, which is capable of making BLE one of the leading technologies for short-range communication in the next generation of networks. This article gives a broad overview of BLE and the different existing methods used BLE for communication. BLE enables smaller form factors, better power optimization, and the ability to operate on a small power cell for several years. I truly believe that this survey would be a source of inspiration towards future developments in techniques to conserve the power in WLANs.

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