Bluetooth: an invention that changed the way we interact with electronic devices.

Kamila Michel, Software Development (Honours), GMIT

Abstract— **Evolution in wireless technology standards in the past decades has made remarkable improvement in our lives. At present, everyone wants to live in comfort away from the wires of our electronic devices. In todays rapid world this is possible thanks to the invention and evolution of wireless communication networks. These technologies offer many benefits such as increased mobility and collaboration, better access to information, easier network expansion and many more. However, there any many different types of wireless networks. Each of them was created for a different purpose. Examples are cellular networks, wireless computer networks, satellite communications or terrestrial microwaves. Although it serves other purposes, the principle of operation of these networks is the same. The purpose of this document is to discuss Bluetooth wireless technology, explain its operation, history, evolution and how its existence revolutionized the market.**

Keywords: Technology, Bluetooth, Networks, Wireless, Communications

I. INTRODUCTION

We live in the world where technology has reached another peak of development. Possibilities of engineering and human imagination allow to invent and produce revolutionary personal devices. Currently, manufacturers are flooding us with additional gadget [3] that help us work more efficiently, monitor the heart rate during sport or simply to entertain. As users, we often want to be able to send data between them. In the past, we did not have much choice in communication except for wired transfer. Examples include transferring photos from the camera to a computer, listening to music from stereo systems or even playing on the game consoles. Fortunately, there is a technology whose invention has greatly helped solve the problem of cables [21]. This invention is called Bluetooth [4] and has been on the market for over 20 years. Bluetooth is a wireless data transfer technology for short range communication up to 10 meters in a straight line. In special cases, the range can be extended up to 100 meters [15]. Bluetooth communicates with other devices sending data (video or audio files [9], as well as the content of phone calls) or controlling the equipment. How does this type of communication work? Bluetooth is a technology of wireless data transmission by means of radio waves, enabling easy communication between various devices. It was created in order to simplify the data exchange and enable running it without constant user supervision. The technology uses radio waves, or electromagnetic radiation [9] from outside the frequency on which most devices operate. Unlike infrared waves [13], radio waves penetrate the walls, allowing Bluetooth to control devices throughout the house without having to aim at the receiver.

II. HISTORY OF BLUETOOTH

It started in 1994, when Ericsson became interested in the possibility of connecting mobile phones without using a cable. To introduce the standard for this type of wireless connectivity, Ericsson together with Nokia, Toshiba, Intel and IBM created the Special Interest Group (SIG) [11]. The standard was to be characterized by low power consumption, small range, low radiation level, and of course a small price. In this way Bluetooth technology replaced cables that were planned to be removed especially in LAN networks. And so, in 1999, SIG published a 1500-page volume describing the first version of Bluetooth V1.0 technology [20].

A. Origin of Bluetooth name

This technology is named [3] after a Scandinavian king living in the 10th century AD. Harald 1 Bluetooth Blatand Gormsson, he was a Viking who ruled Norway and Denmark from 958 to 985. The name Bluetooth is derived from the monarch who was known through a dead tooth, supposedly in a blue-gray shade. Hence his nickname, in Danish meaning simply blue tooth.

B. Generations of Bluetooth

Section below describes the BT technology progression over time. Classic Bluetooth devices are divided into classes, which is related to the maximum output power of the radio transmitter.

- Bluetooth 1.0 and 1.0b Approved in the summer of 1999 [6], the first version of the Bluetooth specification with many problems related to security and reliability [7]. The first version of Bluetooth used a modulation technique called Gaussian Frequency Shift Keyring (GFSK), with this modulation type carrier shifts between two frequencies representing 1s and 0s. Offered transmission speed up to 21 kbps (kilobytes per second).
- Bluetooth 1.1 Many errors found in the previous version have been removed but according to Magnus Berggren [5], there were still issues related to packet transmission loss between different version of Microsoft Windows operating systems. Most likely these were due to bugs in drivers. The ability to combine unencrypted connections and the Received Signal Strength Indicator (RSSI) has been added. Bluetooth 1.1 has been ratified as IEEE Standard 802.15.1-2002. Offered transmission speed up to 124 kbps.
- Bluetooth 1.2 The main improvements are: faster device detection and connections setup. Flow control and retransmission mode have been introduced for

the L2CAP value. Adaptive frequency hopping spread spectrum (AFH) improved communication parameters in a noisy environment by avoiding communication in busy bands. Ratified as IEEE Standard 802.15.1-2005. Offered transmissions speed up to 328 kbps.

- Bluetooth 2.0 Published in 2004 [6]. Frequency modulation has been replaced in favor of two newer schemes p/4-DQPSK and 8DPSK [8]. Both used changes in the waveform to carry information, as supposed to frequency modulation. These changes resulted in much improved transmission speed of up to 2.1 Mbps. This version also offered an EDR (Enhanced Data Rate) enables less energy consumption.

- Bluetooth 3.0 Published in 2009 [6]. BT v3.0 +HS (High Speed) enables reaching the theoretical transmission speed of 24 Mbps. To achieve this, communication runs through two channels: a standard BT channel and WLAN frequencies of 802.11b /s.

- Bluetooth 4.0 + LE Published in June 2013 [6]. It contains a description of Bluetooth Low Energy (BLE), BT High Speed and classic BT protocols. BT Low Energy is a subset of BT v4.0 specifications with a completely new stack of backward compatible products. The main advantage here is the possibility of an amazing reduction in the power demand in the device. As a result, battery-powered devices equipped with BT Low Energy technology can work for a very long time. Therefore, completely new possibilities of their application are opened. For example, the average current consumed by the BT sensors oscillates around microamps. It follows that a 220 mAh coin battery can power it for hundreds of thousands of hours.

- Bluetooth 5 - Published in 2017 [6]. Further improvement in power consumption upon the previous BLE standards. It offers four different data rates to accommodate different applications data requirements. The most important advantages of BT 5 are greater range and greater capacity and potential of serving IoT (Internet of Things) a network of different sensors communicating with each other in home automation systems to please family members.

III. Bluetooth applications discussion

In this section, discussed how the applications using Bluetooth technology have changed and how it affected its development over the years.

A. Bluetooth visions and applications

During the creation of the Bluetooth standard, it was realized that the system would be used to connect and communicate between mobile devices. We believe that Bluetooth can revolutionize wireless connectivity for personal and business mobile devices, enabling seamless voice and data communication via short-range radio links and allowing users to connect a wide range of devices easily and quickly, without the need for cables [14]. This publication included other interesting scenarios regarding the use of Bluetooth

and mobile phones. One of them was "The Briefcase Trick" - it consisted of synchronizing the e-mail client on the phone with the laptop, which was still in the briefcase. Another one was The Automatic Synchronizer it consisted of automatically synchronizing data in the background. For example, when an employee entered the office, he immediately synchronized all contacts, address cards and additional tasks. Both concepts were ahead of their epoch, but the time and further development of other technologies allowed the evolution of other services such as cloud computing and a significant reduction in mobile data costs. Also in this period access to the internet connection has become a standard, and most of the above was achieved using Wi-Fi. The development of mobile phones, in particular the emergence of smart phones, has greatly helped in the development of Bluetooth technology. It was known [10] that this technology will soon be in household appliances, such as washing machines, refrigerators or carrying devices, such as watches. The latest versions have enabled the use of Bluetooth technology in IoT, which contributed to the creation of intelligent home projects.

B. Automotive industry

In 1999 Lars-Berno Fredriksson [12] observed a possible application for Bluetooth module in automotive applications. One of his visions was to utilize car Bluetooth system and have the ability to connect it with the phone, to control the audio system or the door lock mechanism. Another was to use the Bluetooth chip in conjunction with a controller area network (CAN) to reduce wiring harness. As is well known, engineers are still working on the problem cited in this publication. Cars at present still rely on many Electronic Controller Units (ECUs) that are interconnected by kilometers of wires, that can weight in total of up to a hundred kilograms. Currently, modern vehicles have Bluetooth communication as a standard specification, thanks to which users can facilitate communication with audio-information systems and hands-free communication. Unfortunately, probably due to radio waves susceptible to interference, no CAN system was put into production with any wireless technology.

C. Wearables

The development of Bluetooth Low Power (BLE) along with progressive miniaturization has caused growth interest in devices known as wearables, i.e. electronics worn on the body. This branch of electronics is definitely growing in strength. Wearable devices facilitate our everyday life. In addition, the development of these devices along with the smartphones evolution also allowed them to progress on mobile platforms. According to Hidayet Aksu [2] by 2020, there will be 50 to 100 billion devices connected to the internet and one in four smartphone owners will be using a wearable device. Currently, these devices are only gadgets aimed at enabling even more efficient use of smartphones. Watches available today allow you to receive calls, text messages and emails. At the moment they are only an additional display for the phone, so without them

they are useless. However, in the future people will be able to use smart watches as independent devices to make calls, sending texts, transferring photos or use the internet or GPS navigation.

D. Smart Homes

Bluetooth technology is implemented in smart homes [19] where it is used to controls light, temperature, security devices, air conditions and many others home appliances. Current trends [18] show, that there are other reasons why more people would like to have smart home solutions. Among them the most important is the increased sense of security. According to HumanGraph [16] agency, commissioned by Fibaro, conducted a study to show how having smart solutions at home influences the reduction of stress levels. Two groups took part in the study: people with smart home solutions in their homes and those without them. Survey proved that people who do not have smart home solutions feel more emotional tension associated with dangerous situations in their home. Other reason is: Water and energy efficiency, and in the long-term lower house operating costs. A smart home system helps save electricity, gas and water during the hours when people are not there. Also, smart solutions help to heat the house in a way that does not overload the pocket of home owners.

IV. Future

Bluetooth 5.0, which additionally increases the available bandwidth and reduces transmission delays, extends the range and allows for a more flexible use of the IP protocol. Particularly noteworthy is the service of work in networks with mesh [17] topology. A function that is particularly important for smart homes and smart cities. In a network of this type, devices can directly communicate with each other instead of always sending data through a central hub. According to SIG Bluetooth blog [17] with ABI Research expecting 48 billion internet-enabled devices to be installed by 2021, of which nearly one-third will include Bluetooth. As the Internet of Things expands, Bluetooth will continue to develop across the different devices that we use day to day. According to this, we can be sure that the future of Bluetooth is good, and further development is expected. Another strong point that confirmed this assumption was the Apple conference in September 2016 [1]. During the launch of the iPhone 7 Apple discontinued the headphone jack in favor of proprietary lighting port or wireless peripherals. For many users, this solution was not satisfactory due to the inability to charge and listen to music at the same time. This decision imposes the use of Bluetooth as the main standard for audio transmission. This is another example that states the Bluetooth is fine. Now the story is written in front of us, where other smart-phones manufacturers follow Apple trend and drop out the audio jacks.

V. Conclusion

Upon analyzing and investigating this topic, I am convinced that the invention of Bluetooth is more than just getting rid of data cables. Over the last twenty years, Bluetooth has undergone many evolutions in its architecture and has significantly improved its speed, reliability and security. A significant increase in the popularity and demand for smart home solutions only strengthens the position of Bluetooth. The use of this technology by smart phone manufacturers is another driving force behind this technology. I am looking forward to see the future inventions of this technology.

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