BLE Asset Tracking Systems in industry 4.0

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***Abstract*—This paper discusses the use case BLE (Bluetooth Low Energy) Asset Tracking System which is widely used in factories and various types of industry 4.0 businesses including logistics, production, retail and simply every section holding physical assets. In this technology the items are equipped with a small device called beacon and using that communicate with some other wall-mounted equipment through BLE and in this way, the exact location of the items gets discovered utilizing a software platform. There are other types of asset tracking systems based on wireless communication technologies like Barcode and QR code, GPS, LoRa, ZigBee and 5G**

Keywords—Asset Tracking, BLE, Wireless Communication,

I. INTRODUCTION

After the emergence of industry 4.0 which comprises and highlights the most recent technological novelties in high-paced and mostly customized manufacturing [1], due to an abrupt growth of the industries—in terms of both number and size—some new requirements also came to play which demanded its own solutions one of which is the necessity of having a much more accurate surveillance of the assets and belongings of the business. Asset tracking is a very clear example of these demands which was born due to the increasing number of mislocated and lost assets and deliveries.

One of the first and earlies asset tracking technologies which accompanied the industry 4.0 movement was RFID. In 2010 after the expenses of producing tags and equipment reduced and its dependability and accomplishment was verified, using RFID started to increase enormously worldwide [2] and this can be named as the commence of the new generation of the asset tracking technology. Due to development of new wireless communication technologies like Bluetooth, BLE, Zigbee, Lora, IEEE 802.11 and lately 5G and attaining a better understanding of how effective asset tracking can be in industries, various types of asset tracking system using different technologies, according to the environment, characteristics of the use case and the requirements the industry gradually started to be utilized.

In this paper the different types of asset tracking system will briefly be discussed then BLE asset tracking technical characteristics, requirements and challenges of the wireless connection technology will be introduced, at the next step link layer and the physical layer of BLE asset tracking system will be investigated and finally possible future development will be studied.

II. DIFFERENT TYPE OF ASSET TRACKING SYSTEMS ACCORDIN TO WIRELESS TECHNOLGY

the development of the wireless technology made this possible by attaching a tracker device to an item which communicates to a transceiver and this way it would be relatively easy to track down mislocated or lost items in almost no time. According to the environment characteristics of the use case and the requirements there are multiple kinds of asset tracking systems which does the job using different wired and wireless technologies. Each of these technologies has made this possible for these types capable of working in different environments:

A. Barcode and QR code, RFID and NFC

This type of technology, which is called product identification method, offers a huge amount of data encapsulated within a tiny space and has numerous advantages like saving time and work force and increasing the speed of operations. There is nevertheless a huge different between these three technologies. First two do not use wireless technology directly and use wired or wireless scanner which scans the barcode or QR code via laser beams and translates it into information. RFID, which is discussed before, consists of electromagnetic labels which can be read by some receivers using radio multiple frequency bands depending on which type it is (low, high, ultra-high, microwave frequency) [3]. NFC or near-field communication uses the same technology as RFID but there are subtle differences between two, like the physical range of coverage which is up to 100 meters for the former and about 4 cm for the latter and while RFID provides a one-way data delivery, in an NFC connection data can be sent and received on both sides. NFC communicates in two modes, active which is the device that starts the communication and creates its arbitrary radio frequency field and the passive mode which is the device that needs to follow the other side's frequency rules to get into the communication. NFC uses Manchester encoding scheme and modified Miller encoding on the physical layer [4].

B. GPS (Global Positioning System)

GPS is a navigation system uses 24 satellites electromagnetic waves to build a network which makes the system capable of tracking down the items carrying GPS tracker device almost anywhere in the world [5]. Using GPS does not need any license and has no fees which makes it so attractive for different uses cases. GPS frequency band fluctuates between 1176 MHZ to 1575 MHZ depend on which spanning band it uses form L1 to L5 [6]. GPS uses binary phase-shifting key (BPSK) as the modulation technique on the physical layer and code-division multiple access (CDMA) as media access scheme on the MAC layer [7].

C. LoRa (Long Range) and 5G

LoRa prepares a tracking system within a quite large physical range which is approximately 10 kilometers. It uses a mesh decentralized network for tracking, and this makes it resilient to network failures. The equipment which are used in LoRa asset tracking is also very cheap and accessible [8]. LoRa operates on Industrial, Scientific, and Medical (ISM) bands on 915 MHZ in USA and 868 MHZ in Europe [8]. LoRa uses a technique similar to Aloha as the channel access technique in MAC layer [9].

5G which is cellular network technology, also prepares asset tracking in long range which can be fluctuating depending on the number of towers used in the area, but each tower individually can cover a range of roughly 500 meters [10]. 5G uses frequency spectrum band between 28 GHZ and

39 GHZ and it uses OFDM as encoding technology as its successor LTE does. LoRa compared to 5G is ultimately cheaper, more accessible and consumes less energy.

D. ZigBee

Among all asset tracking technologies mentioned earlier, ZigBee is considered the closest to BLE concerning the general characteristics and usage environment conditions. ZigBee uses 2.4 GHZ frequency within 16 channels, it's based upon IEEE 802.15.4 standard [11] and its network topology is established on mesh network which makes it relatively slow in comparison with other techniques [12]. ZigBee is considered as a low-rate wireless communication technology as it has a bit rate of only 250 kb/s [11]. Although it is known as a low-power wireless communication technique, it uses substantially more power than BLE (15.0 uA vs 10.1 uA) [13]. There are multiple differences between ZigBee such as, the range of physical coverage which is 77 meters for BLE and approximately 300 meters for ZigBee; BLE can operate on both mesh and star topology while ZigBee only works under mesh; BLE uses frequency hopping spread spectrum (FHSS) modulation while ZigBee uses direct sequence spread spectrum (DSSS) [12].

III. BLE ASSET TRACKING TECHNOLOGY GENERAL DESCRIPTION AND REQUIRMENTS

BLE asset tracking specifically, has unique specifications like low power consumption, short distance range adaptation, inter network devices communication, fit for the devices in which low battery life matters the most and also has characteristics like real-time indoor tracking, being cloud based, productivity continual assessment and etc. Due to the multiple facilitating specifications and characteristics, there are quite a few industries which can utilize BLE like, manufacturing factories, some parts of logistic industries, agriculture, educational environments, medical related industries and warehouses.

BLE asset tracking system requires multiple components like:

- BLE tags which is also called beacons, these are fairly small battery powered piece of hardware attached to the asset which needs to be tracked and communicate with other beacons or devices via low-energy Bluetooth (BLE) technology [14];
- BLE scanners which are located within the environment in which the assets are being located and moved. these are nothing but some fixed beacons which communicate with mobile ones and using their unique ID make the tracking task possible through determining the exact location and moving direction of the items. Because BLE covers a quite short range of distance it's often necessary to have multiple scanners within the operation areas so that the continual item tracking will be guaranteed.
- And the last component is BLE platform which depending on the version of BLE tracking system, can be a multi-layer architecture platform consisted of fog computing platform, a subscribe and/or publishing framework, machine learning-aided software which does the decision making and etc. [15]. the bundle of different layers translates and controls the signals and interpreted the information to an understandable form like graphical interface for the user or provides embedded services such as APIs which can be used as an interface in other platforms based on the use case.

IV. TECHNICAL CHARACTERISTICS AND CHALLENGES OF THE WIRELESS COMMUNICATION

BLE asset tracking system uses Bluetooth Low Energy (BLE) as the wireless connection technology which is an enhanced version of the traditional Bluetooth by decreasing the power consumption specifically tailored to be introduced to the new generation of smart devices. This modification has made BLE relatively different from its traditional version. This difference starts from the physical layer. Bluetooth was developed as an alternative for the existed wired connected and as a solution for transferring bulk data while BLE is designed especially for sending aggregated data within periods of time [16]. Also, the most explicit difference between two is as mentioned the energy consumption which makes the BLE very efficient in battery powered devices.

A. Physical Layer

BLE utilizes 2.4 GHZ ISM band frequency and uses 40 channels which have the inner spacing of 2 MHZ meaning each channel is spread within the capacity of 2 MHZ. BLE basically operates in two modes: advertising mode and data transfer mode. There is an individual type of channel specified to each by the physical layer and each type of packet is transferred through its corresponding channel. channels 1, 6 and 11, has been assigned to advertising communication and remaining are for data. The frequencies which have allocated to advertise channels are at the middle of the frequency range to avoid any collisions with IEEE 802.11 standard [17].

BLE uses adaptive hopping mechanism (AFH) to choose one among 37 data channels for establishing a two-way communication between two devices. This mechanism takes over the problems which might occur concerning signal collisions, fading and multipath propagation etc. [17][18].

All individual channels transfer data using Gaussian Frequency Shift keying (GFSK) which filters [18] the pulses using a gaussian filter before undergoing the modulation. In this way, the modulation process enhances, and several advantages are reached such as: interference reduction and sideband power [19]. Therefore, the modulation index reaches 0.5 which decreases peak power consumption. The data rate in BLE physical layer in versions 4.0, 4.1 and 4.2 is 1Mbps but BLE version 5.0 has the data rate of 2 Mbps. This has happened by the result of using shorter TXs and RXs in BLE version 5.0 while leaving inter-frame space unchanged from older versions. In Fig 1 values of TX, RX, and INF-S in both versions 4.2 and 5,0 are demonstrated [20].

Version	TX	RX	T-INFS
BLE v 4.2	328µS	80µS	150µS
BLE v 5.0	164µS	40µS	150µS

Fig 1. Difference between BLE versions 4.2 and 5.0 [20]

B. Data Link Layer

The process in Data link layer in BLE is consisted of three subprocesses:

- Advertisement: In BLE when a device aims to transmit data to another device, the first is getting the advertiser role and sending advertisement data through one of three advertising channels to the scanner. The advertiser in this way tries to identify the scanner and prepare to establish the connection for transferring the data [19].
- Scanning: This process is listening for incoming advertisements on the advertisement channel and is done by the scanner devices.
- Connecting: After two previous operations, the advertiser and scanner get connected and get ready to transfer data. Establishing connection occurs via physical data channels. The two advertiser and scanner are known as slave and master roles in BLE [17]

Every slave will be able to get connected to just one master, but a master is able to get connected to multiple slaves. Both the master and slaved for a star network which is named a piconet. To keep the energy consumption of the nodes as low as possible, the slaves will stay in hibernation mode (temporarily deactivated) and get reactivated every once in a period to check if they there have been a packet sent from master.

As the master is connected to multiple nodes, BLE utilizes Time Division Multiple Access scheme (TDMA) to enable the master to manage multiple access to the different slaves. And to control the and discover errors in the connection a 24 Cyclic bit Redundancy (CRC) is used.

V. CHALLENGES

Like other wireless communication technologies, BLE also has two main challenges. The first one relatively low physical range and the second very low transfer speed. As we have witnessed how fast industry 4.0 happened and surpassed the how world and affected all the industries, undergoing another evolutional disruption will be inevitable. Considering the current challenges which is assumed a very serious bottle neck for BLE, by increasing the amount of data which needs to be transmitted and the need for high-speed data transfer will push the BLE away and replace it with optimized versions [21].

Also, by simply looking at BLE alternative technologies, it can be understood that by enhancing the weaknesses of theologies like ZigBee they can simply be substituted by BLE.

VI. FUTURE DEVELOPMENT

BLE has the capacity of enhancing for an ultimately better version. This can be happened by the emergence of highly efficient multiple accessing schemes and modulation techniques. For example, one of the challenges of the BLE is that in the future BLE should be more energy saving. This can happen by using more advanced modulation techniques. Also by using much bigger frequency range and consequently more channels, the number of connected slaved in each piconet can be improved.

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