SLOVENSKI STANDARD
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Javni prevoz - Medobratovalni sistem upravljanja voznin - Primeri in smernice za uporabo vozovnic, ki temeljijo na tehnologiji BLE (bluetooth low energy)

Public transport - Interoperable fare management system - Bluetooth low energy ticketing use cases and guidelines

Öffentlicher Verkehr - Interoperables Fahrgeldmanagement System - Niedrigenergie-Bluetooth Anwendungen und Vorgaben für den Fahrkartenverkauf

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35.240.60	Uporabniške rešitve IT v prometu	IT applications in transport

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TECHNICAL REPORT

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CEN/TR 17311

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ICS 35.240.60

English Version

Public transport - Interoperable fare management system - Bluetooth low energy ticketing use cases and guidelines

Transport public - Système de gestion tarifaire interopérable - Cas d'utilisation et lignes directrices pour l'usage du Bluetooth faible énergie dans les applications de billetterie

Öffentlicher Verkehr - Interoperables Fahrgeldmanagement System - Niedrigenergie-Bluetooth Anwendungen und Vorgaben für den Fahrkartenverkauf

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European foreword

This document (CEN/TR 17311:2019) has been prepared by Technical Committee CEN/TC 278 "Intelligent transport systems", the secretariat of which is held by NEN.

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1 Scope

The intention of this document is to review what was done to envision the limits of the proposed technique and related schemes which will be described and to define what could be submitted to standards. Concepts which are to be used for BLE in IFM are based on a highly spread technology which is BLE. This is not limited to any trademark or proprietary scheme. Therefore any person having a smartphone can use this technology with prerequisite to have a Bluetooth version greater than 4.0 and a dedicated application on board the smartphone.

The background of this document is related to usage in Account Based Ticketing frame (see related document made in ISO/TC 204/WG 8). There is no information related to the IFM itself.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Symbols and abbreviations

TR Technical Report

EN European Standard

5 Introduction to BLE

5.1 What is BLE

Bluetooth low energy (BLE) is a wireless personal area network technology designed and marketed by the Bluetooth Special Interest Group aimed at novel applications in the healthcare, fitness, beacons, security, and home entertainment industries. Compared to Classic Bluetooth, BLE is intended to provide considerably reduced power consumption and cost while maintaining a similar communication range.

The Bluetooth Low Energy identifies a number of markets for low energy technology, particularly in the smart home, health, sport and fitness sectors. Cited advantages include: low power requirements, operating for “months or years” on a small size button cell and low cost compatibility with a large installed base of mobile phones, tablets and computers.

Compared to classic Bluetooth technology, BLE has the characteristics as shown in Table 1.

Table 1 — Comparison between classic Bluetooth and Bluetooth Low Energy

Technical specification	Classic Bluetooth technology	Bluetooth Low Energy
Distance/range (theoretical max.)	100 m	> 100 m
Over the air data rate	1 Mbit/s to 3 Mbit/s	125 kbit/s – 1 Mbit/s – 2 Mbit/s
Application throughput	0,7 Mbit/s to 2,1 Mbit/s	0,27 Mbit/s
Active slaves	7	Not defined; implementation dependent
Security	56/128-bit and application layer user defined	128-bit AES with Counter Mode CBC-MAC and application layer user defined
Robustness	Adaptive fast frequency hopping, FEC, fast ACK	Adaptive frequency hopping, Lazy Acknowledgement, 24-bit CRC, 32-bit Message Integrity Check
Latency (from a non-connected state)	Typically 100 ms	6 ms
Minimum total time to send data (det. battery life)	100 ms	3 ms
Voice capable	Yes	No
Network topology	Scatternet	Scatternet
Power consumption	1 W as the reference	0,01 W to 0,50 W (depending on use case)
Peak current consumption	< 30 mA	< 15 mA
Service discovery	Yes	Yes
Profile concept	Yes	Yes
Primary use cases	Mobile phones, gaming, headsets, stereo audio streaming, smart homes, wearable, automotive, PCs, security, proximity, healthcare, sports and fitness, etc.	Mobile phones, gaming, smart homes, wearable, automotive, PCs, security, proximity, healthcare, sports and fitness, Industrial, etc.

BLE uses the same frequency band as Bluetooth (2,4 GHz to 2,5 GHz) and shares this frequency band with other uses (notably WiFi which uses the frequency band 2,4 GHz to 2,6 GHz). To allow for less sensitivity to disturbances, BLE implements a frequency hopping mechanism, thus ensuring clear data transmissions even in rich media of radio links.

Moreover, BLE allows a varied use in terms of implementation since this protocol can be used:

— In connected mode: 2 interlocutors dialogue once paired;

— In network mode: 1 master allows the establishment of a communication with several slaves in a pico-network;

— In beacon mode: 1 element transmits information that anyone who wants to hear can hear.

Last mode looks to be the most popular to applications used in IFM systems even if some implementations in connected mode have been tested.

BLE interest increases because Bluetooth function is present on all smartphones whatever the manufacturer is. Different approaches were made to envision BLE usage in the IFM world. Several usages have already been described as well as POCs were made with different concepts.

The use of BLE is covering specifically the functionality. It can apply to open systems with surface vehicle (bus, tramways, BRT [Bus Rapid Transit: bus with high service level]) as well as closed systems used in metro with physical gates.

5.2 BLE ecosystem analysis

5.2.1 Introduction

Bluetooth is a standard for Personal Area Networks (PAN) which was developed by Ericsson research group in 1994. This technology is considered to be a short range and low power technology. This operates in the Industry Security Medical (ISM) frequency band of 2,4 GHz. Bluetooth has been adopted by most of the Information and Communication Technology industry since its acceptance by the Bluetooth special interest group (SIG) in 1998. The SIG board members include mobile manufacturing giants at that time (e.g. Apple, Microsoft and Motorola) and silicon chip manufacturers (e.g. Intel, Nordic semi-conductor). The term Bluetooth has evolved since 2000. First standard was Basic rate which focused on short range networks like Personal Area Networks. It typically had ranges from 10 m to 100 m. It was using frequency hopping spread spectrum techniques. Data rates of 1 Mbps were achieved. The next standard was introduced as enhanced data rate. This updated standard offered higher data rates of 2 Mbps to 3 Mbps. In 2008, the High Speed was introduced, which offered data rates up to 24 Mbps.

However ICT industry also felt a need for low energy version which would facilitate short distance and low power networks. Advances in battery technology also imposed challenges on these earlier versions of Bluetooth. There was a need for advanced version of Bluetooth which would be used in accessories that uses less battery and required less power which lead to the latest additions in Bluetooth, known as Bluetooth Low Energy (BLE).

5.2.2 Key Features of the Bluetooth Low Energy

Bluetooth Low Energy is the newly designed and a complementary technology to the classic Bluetooth. It is the current lowest possible power wireless technology. This technology borrows its name from its parent which had a basic rate of 1 megabit per second (Mbps) and was known as Basic Rate (BR). Enhanced Data Rate (EDR) was version 2 which had a data rates to 3 Mbps. Version 3 which is known as Alternate MAC PHY (AMP) delivered data rates up to hundreds of megabits per second. However, BLE provides lesser data rate compared to AMP but instead optimized for ultra-low power consumption by virtue of its design which means that the Bluetooth connection can be maintained for a longer duration, say hours or days.

5.2.3 Bluetooth single mode and Bluetooth dual mode

Since Bluetooth devices came into existence in the late 1990´s. There are already several devices in the market which support versions 1, 2 and 3. These are called the Bluetooth classic only devices. They have architecture as shown in Figure 1. Two new devices are also built which are known as dual mode and single mode devices. A single mode device is a Bluetooth device that supports just the BLE. Devices that support both BLE and the classic Bluetooth are called dual mode devices. Their architectures are as shown in Figure 1 respectively.

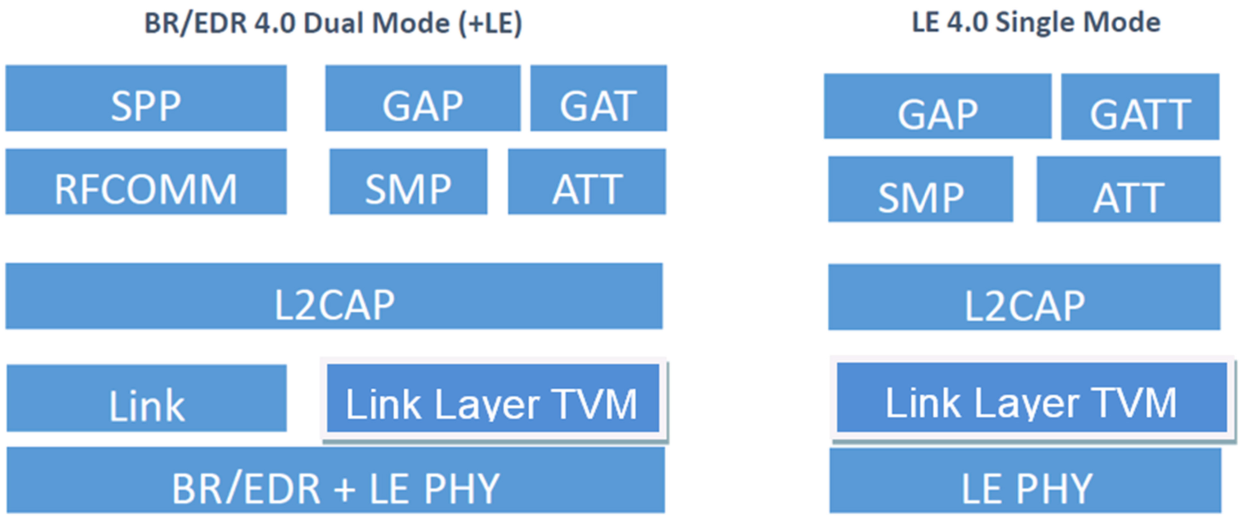

Figure 1 — Bluetooth Dual Mode and Single Mode Architectures

In the market the dual mode and single mode devices are sold as Bluetooth smart ready and Bluetooth smart devices. Each of these modes has its own architecture as shown in Figure 3. Since Dual mode devices support both Classic and LE, these devices can talk with all the versions of Bluetooth. However, single mode also known as Bluetooth smart devices can only communicate with the Bluetooth smart ready also known as dual mode devices.

Dual mode devices are new in the market and they require new hardware and firmware in the controller and software in the host. It is because of this reason that existing Bluetooth Classic controller cannot be upgraded to support low energy. The single mode devices are highly optimized for low power consumption which is powered by button cell batteries. Since applications like public transport systems rely very much on low power and less battery consumption an attempt is made in this frame to implement BLE usage in ticketing systems. The following section will introduce the complete architecture of the Bluetooth Low Energy.

5.3 Bluetooth Low Energy Architecture

5.3.1 General

The BLE architecture can be divided into three main parts:

— Controller

— Host

— Profiles.

The controller is a Radio which has Physical Layer (PHY), Link Layer (LL) and a Host Controller Interface (HCI).

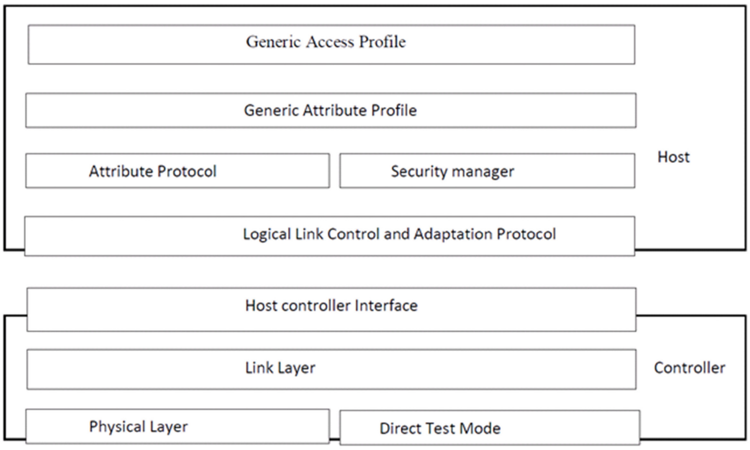

Figure 2 — Architecture

Figure 2 represents the layered architecture. It is termed layered because it consists of so many layers which are placed on top of each other. Physical layer is the bottom most layer which receives and transmits bits of information. The link layer considers these bits as packets of data and it controls these packets and sends this data in various procedures and protocols. The Host Controller interface (HCI) is the next layer which acts as an interface between the Controller and the Host. The logical link control and adaption protocol also known as L2CAP acts as a multiplexer to the number of channels which are present on top of the controller. The attribute protocol which is on top of L2CAP is the protocol which is used to access the data on a device. It helps in reading, writing and various other functions on the device. The generic access profile provides various services which are present in the device. It gives first-hand information of how things are organized on the device. It also consists of Meta attributes and various characteristics of the device which define the organization. On top of these lie the applications. Various applications like battery profiles, temperature profiles, proximity, heart rate monitor, etc. are defined and developed over this space.

5.3.2 The controller

The controller can physically be represented as a hardware which is a Bluetooth chip or radio. It consists of analog and digital parts which are embedded onto a silicon chip which supports the transmission and reception of the data packets. Companies like Nordic semiconductor, Texas instruments manufacture the controller and sell them in the market with various commercial names. An example of the same is the Nordic semiconductor kit. It is to be understood that the physical layer is an nrf51822 Radio.

5.3.3 Physical layer

This layer is responsible for transmitting and receiving the data in the form of bits using the 2,4 GHz radio. BLE uses Gaussian frequency shift keying (GFSK) which means ones and zeroes are coded onto the radio by slightly shifting the frequency up and down. Whenever there is an abrupt frequency shift, at that moment a pulse of energy spread's out over a wider range of frequencies. To enable to stop the energy spreading into these high and low end frequencies a Gaussian filter is used. This is called Gaussian because the transfer characteristics of this filter looks like a Gaussian curve. This also implies that low energy signal spreads out more than a standard Bluetooth classic radio signal since it doesn't use a tighter filter. Due to this reason the BLE is governed under the spread spectrum radio regulations as against frequency hopping mechanisms used by its parent technology.

So the modulation index used in the case of BLE is slightly higher than the classic Bluetooth which implies more number of channels to be used. In this case, the 2,4 GHz band in case of BLE is split into 40 separate RF channels each of them are 2 MHz apart from each other. In 40 RF channels three channels are fixed channels which are used for advertising data. The remaining 37 channels are used for transmitting application data and are dynamic in nature. In this band channel 37, channel 38 and channel 39 are the advertising channels and the remaining channels are the data channels used to send data. So when a device is adverting data it implies that the data are being sent over one of the 3 adverting channels. And the reason the advertising channels are placed in this manner is to avoid the WiFi channels which operate on the other frequencies.

One of the main reasons that BLE uses 3 advertising channels is that it allows the devices to be discovered and connectable over a given period of time. It also makes the system more robust which also means it gives low power. Another reason being, if one device needs to be connected than one of the advertising channels is used and the device which is scanning discovers this advertisement than it takes around 1,3 ms to complete this connection. So with 3 channels it gives a very fast connection, which implies its duty cycle is ten to twenty times better than classic Bluetooth which also proves that BLE is more power efficient.

5.3.4 Link Layer

Link layer is the next layer which is on top of the physical layer and is below the L2CAP layer. This is more complex layer which ensures that the packets are structured so that the key functionalities like advertising, scanning and creation and maintenance of the connection is taken care of. To enable the link layer to perform these functionalities channels, packets and procedures are defined in the Bluetooth specifications. Various channels, packets and their structures will be explained in detail in the next chapters.

The best way to visualize the link layer is to understand it as a state machine. This state machine has five different states. Standby state is the first state where nothing is done. As soon as a device is switched on, it is assumed that it is in standby state. It is possible to move into advertising, scanning or initiating states from this state. So this is in the Centre state and the most important and inactive state in the state machine.

Advertising state: from the stand by state it is possible to get into advertising state. By doing this the device transmits advertisement data packets. If a device needs to be discovered or connectable, the device shall get into this state. This state is also mandatory if the device has to broadcast some data. From this state it is also possible to respond to scan requests from devices which are actively scanning the device under test.

A device in scanning state will receive advertising data packets from the advertiser. Passive and active scanning are two types of scanning sub states. In passive scanning it is just possible to hear the advertisements. However in active scanning, scan requests can be sent to obtain additional scan response data. As the state machine suggests, it is only possible to get back to the stand by state from scanning state.

To initiate a connection with any device, the state machine shall be in the initiating state. In this case the device will listen to the initiators message. If an advertisement packet is received from this device than link layer will send a connect request to the advertiser. So the device gets connected. In case the connection shall be dropped then the initiator can stop initiating and get back to stand by state by just stopping a initiating a connection.

The final state of the link layer state machine is the connection state. This can be achieved either via advertising state or through the initiating state. It is performed under the initiator state than the device is said to take the role of master. Once the connection is established through the advertisement, it takes the role of slave. Master and slave are the two sub states in this connection state. Also the connection state is achieved by making use of the data channels. All other states make use of advertising channels.

To send data on any of the above mentioned channels through any of these states, it is done through packets. A packet is a small encapsulation of data that is sent from transmitter to receiver over a short period of time, which structure is shown in Table 2.