



WAVE

TECHNICAL PRODUCT DESCRIPTION

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REFERENCE

Reference	Document / link	Description
[1]	MyNewt	MyNewt Website
[2]	LoRaWAN Stackforce	LoRaWAN stackforce website.
[3]	MCUBoot	MCUBoot website

GLOSSARY

Abbreviation	Description
BLE	Bluetooth Low Energy
FSK	Frequency Shift Keying
IFA	Inverted-F Antenna
IoT	Internet of Things
LED	Light Emitting Diode
LPIoT	Low Power Internet of Things
LoRaWAN	Long Range Wide-Area Network
MCU	Microcontroller
MIPS	Million Instruction Per Second
OS	Operating System
PCB	Print Circuit Board
PSRAM	Pseudo Static Random-Access Memory
SRAM	Static Random-Access Memory
SPI	Serial Peripheral Interface
USB	Universal Serial Bus

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1. Introduction

The Wanesy™ WAVE is a product based on Kerlink Low Power IoT Reference Design solution. It consists of a Wi-Fi and BLE device with a LoRaWAN™ backhaul. The device notably provides the following functionalities:

- Communicate in LoRaWAN™
- Different Wi-Fi services
- BLE services

Main purpose of the device is for tracking, using Wi-Fi probe requests collection from Smartphones when doing people counting or Bluetooth Low Energy scanning and zoning when doing asset tracking.

It can then answer several questions such as:

- “How many people and/or assets are in that specific area?”
- “How many people and/or assets have been in that place for more than 10 minutes?”
- “Which are the new assets seen within the last 10 minutes?”
- “What is the list of assets in that area?”
- “Where is this specific asset?”

2. Functioning



Figure 1: IoT value chain

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3. Hardware architecture

3.1 Block diagram

The hardware architecture is described in the following diagram. It is based on Kerlink Low Power IoT Reference Design hardware architecture (in blue) with additions specifically designed for the wave product (in yellow).

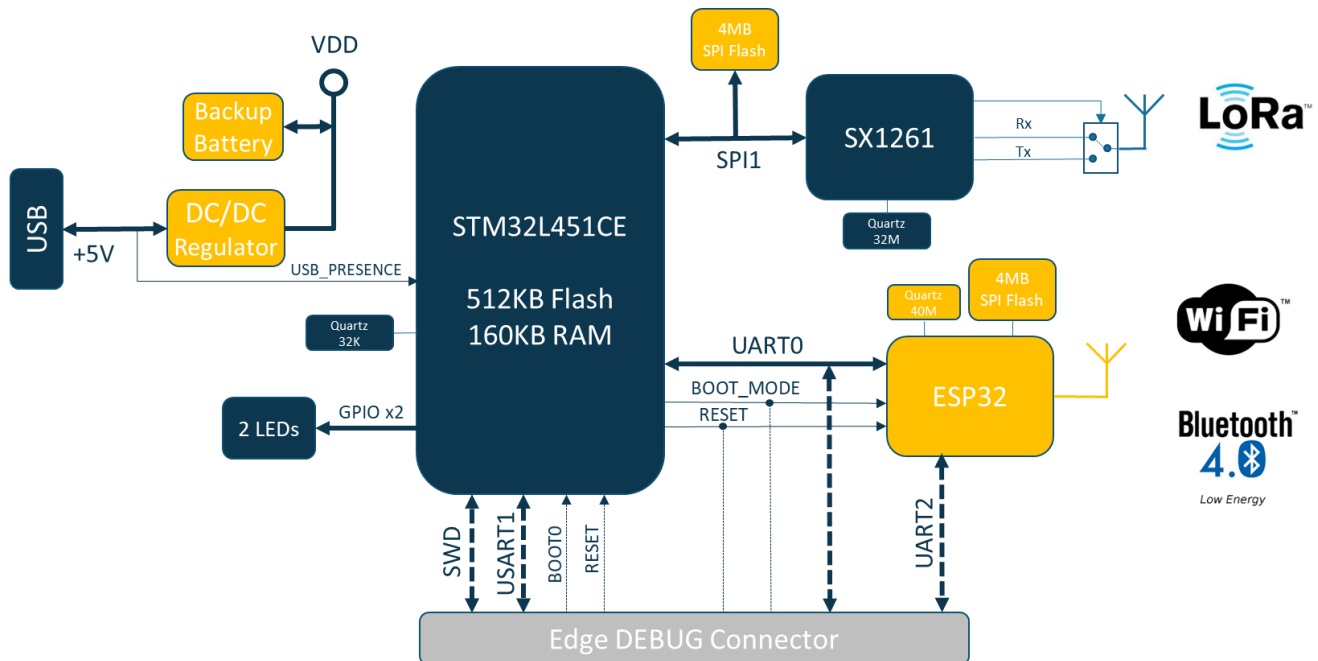


Figure 2: Hardware block diagram

3.2 Functionalities overview

Wanesy™ WAVE integrates several features:

- STM32L4 MCU:
 - ARM Cortex M4 80MHz core, under MyNewt OS
 - Non-volatile memory: 512kB internal Flash + 4MB external SPI Flash
 - Volatile memory: 160kB SRAM
 - Full specification documentation available here: [STM32L451CEU6](#)
- LoRa™ radio: SX126x:
 - LoRa™ & FSK modem
 - Frequency range from 863MHz to 928MHz
 - Conducted Transmit power: up to 15dBm (SX1261) or 22dBm (SX1262)
 - RX sensitivity (LoRa™ modulation): down to -137dBm

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- ESP32 MCU:
 - Xtensa® dual-core 32-bit LX6 microprocessor(s), up to 600 MIPS
 - Non-volatile memory: 448kB internal ROM + 4MB external SPI Flash
 - Volatile memory: 520kB SRAM + 8MB external SPI PSRAM
 - BLE Radio:
 - Bluetooth 4.2 BR/EDR BLE dual mode controller
 - Class 1, 2 & 3 transmitter
 - Output power: up to +12dBm
 - Sensitivity: down to -97dBm
 - Wi-Fi Radio:
 - 802.11 b/g/n/e/l (802.11n up to 150 Mbps)
 - Automatic Beacon monitoring
 - 4 × virtual Wi-Fi interfaces
 - Output power: up to +14dBm or +20dBm (11b mode)
 - Sensitivity: down to -98dBm

- Powered by DC supply:
 - 5V DC supply via USB connector
 - 3.0V Backup battery solution to manage USB cable disconnection

- 2 programmable LEDs as user interface:
 - 1 green LED
 - 1 red LED

- Micro-B USB connector

- Debug edge connector (for production and debug only)

- Operating temperature range: -20°C to +55°C

- Storage temperature range: -40°C to +85°C

- For indoor use only (IP30)

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3.3 LoRa® radio specifications

3.3.1 LoRaWAN

The LoRaWAN connectivity is provided by the:

- [SX1261](#) for the EU868 version
- [SX1262](#) for the US915 version

3.3.2 LoRa® RF characteristics

The radio front-end is derived in two different versions to cover the unlicensed bands. The RF characteristics of the radio chipsets are detailed below:

Feature	868MHz	915MHz
Max output power	+15dBm	+22dBm
Rx Band	863-874.4MHz ¹	902-915MHz
Tx Band	863-874.4MHz	923-928MHz
Sensitivity	SF12-BW125: -137dBm	SF12-BW500: -129dBm
Standard compliance	EN300 220-2	FCC part 15.247

3.3.3 LoRa® antenna

3.3.3.1 Specifications

The specifications of the omnidirectional LoRa® antenna are the following:

Item	868MHz	915MHz
Frequency range	862-873MHz	902-928MHz
Impedance	50 ohms	
Technology	Meandering monopole	
VSWR	<2:1	
Max gain	2dBi	
Polarization	Linear	

3.3.3.2 Radiation patterns

Radiations patterns of the LoRa® antenna is presented below:

¹ 874.4MHz is considered as a future evolution of unlicensed band in Europe

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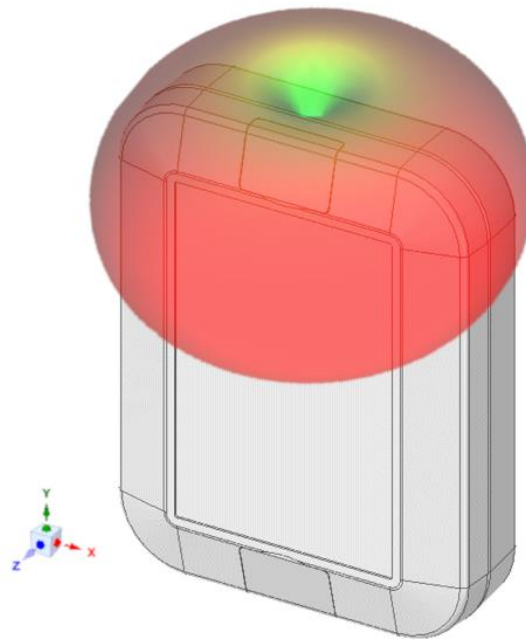


Figure 3: LoRa® antenna theoretical radiation patterns

3.4 Wi-Fi and BLE specifications

3.4.1 Microcontroller

The Wi-Fi and BLE feature of Wanesy™ Wave is supported by an ESP32 microcontroller from Espressif: [ESP32-D0WDQ6](#)

3.4.2 2.4GHz antenna

3.4.2.1 Specifications

The specifications of the omnidirectional 2.4GHz antenna are the following:

Item	2.4GHz
Frequency range	2.3 – 2.7GHz
Impedance	50 ohms
Technology	IFA
VSWR	<2:1
Max gain	2dBi
Polarization	Linear

3.4.2.2 Radiation patterns

Radiations patterns of the 2.4GHz antenna is presented below:

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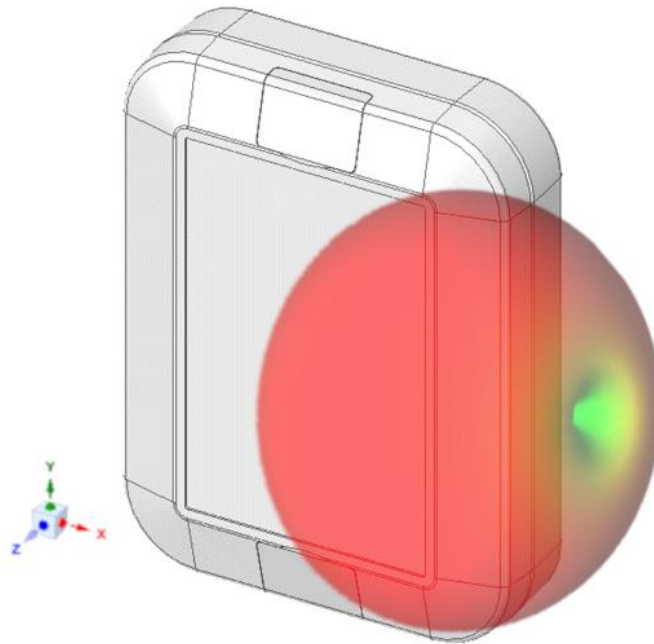


Figure 4: 2.4GHz antenna theoretical radiation patterns

3.5 Power Supply

3.5.1 5VDC USB power supply

The Wave product is power supplied by an USB +5V ($\pm 5\%$) 1A power source. The connector is a μ USB connector. The micro-B USB connector is located at the bottom side of the product as shown below:



Figure 5: View of micro-B USB connector

The main “DC” characteristics of the USB interface are detailed below:

Description	Specification
Connector type	micro-B USB female socket
Input voltage (sink port)	5VDC typ 4.75V DC min, 5.25VDC max
Input current (sink port)	1A min, 3A max

A USB presence signal is connected to the STM32 microcontroller in order to detect plug/unplug of the USB cable.

Note: The USB connector is only used to power supply the product.

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3.5.2 Backup power supply

Wanesy™ WAVE is equipped with a rechargeable backup power battery to allow continuous operation a few minutes after the loss of the power supply or when USB power supply is disconnected.

The backup battery is designed to allow the emission of a few LoRaWAN frames (for example). The backup battery solution is rechargeable.

- Seamless switch between backup and USB supply.
- Entering low-power mode when USB disconnection is detected.
- Automatically recharging the backup battery as soon as USB is plugged back.

Description	Specification
Battery capacity	1.0mAh
Battery charging time (from 0V)	Approx. 7h
Stand-by operating time	Up to 20min (1 LoRa Tx, No Wi-Fi, No BLE)

3.6 User interface

3.6.1 LEDs

Wanesy™ WAVE has two LEDs located on the front side of the product as described below:



Figure 6: View of LEDs

They are driven by the STM32 microcontroller. The LEDs are used to indicate the following behavior:

Item	Specification
LED 1 (Green):	ON: USB Power connected OFF: USB Power disconnected
LED 2 (Red):	ON: LoRaWAN join request sent, waiting for accept. OFF: During boot or LoRaWAN network joined.

3.6.2 USB connector

The USB connector is used as a power supply interface of the Wave product. It has no other purpose.

3.6.3 Debug interface

The debug interface of the Wave product allows to access signals of the STM32 and ESP32.

STM32 :

- SWD
- UART1
- Boot
- Reset

ESP32 :

- Boot_mode
- Reset
- UART0
- UART2

The debug interface is only available using a debug probe (Kerlink specific) and has been designed for production and development purposes. Removing the casing is necessary to access the debug interface. Please note that opening the casing voids the warranty if any applies.

3.7 Memory

Two SPI flash memory of 4MB are connected to the STM32 and ESP32 (one for each): for example: [W25Q32JVSSIQ](#).

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4. Mechanical implementation

4.1 Casing description

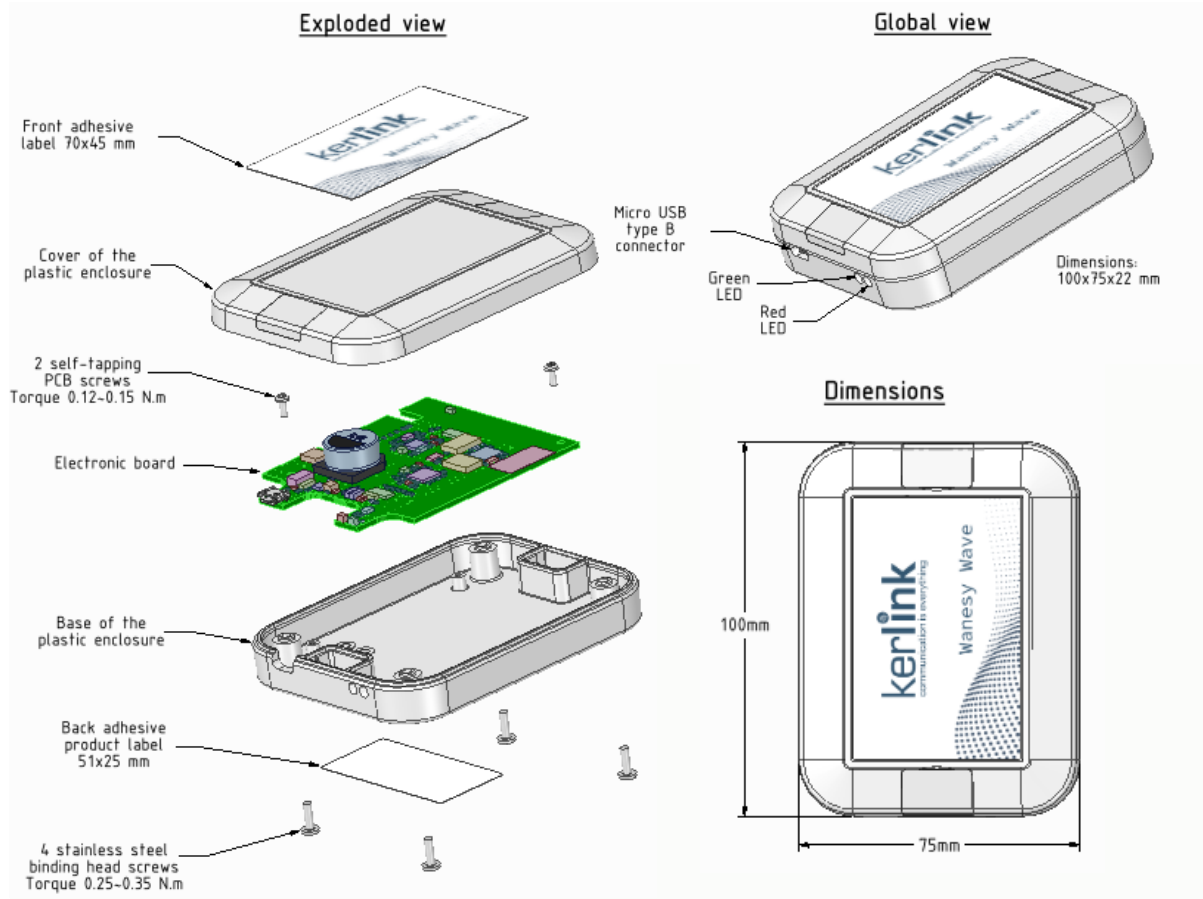


Figure 7: Views of the casing

4.2 Casing characteristics

The Wave product casing is a Takashi WP8-10-2G (plastic enclosure). The main characteristics of the enclosure are detailed hereafter:

Description	Specification
Enclosure material	ASA (UV-resistant)
Color	White gray
Dimensions	100 x 75 x 22mm
Weight	74g
Ingress protection	IP30
Flammability rating	UL94HB
Operating temperature	-30 to +60°C

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4.3 Mounting

Two Ø3.3mm holes are usable to fix the product. These holes are hidden behind the blind lids and will not be visible

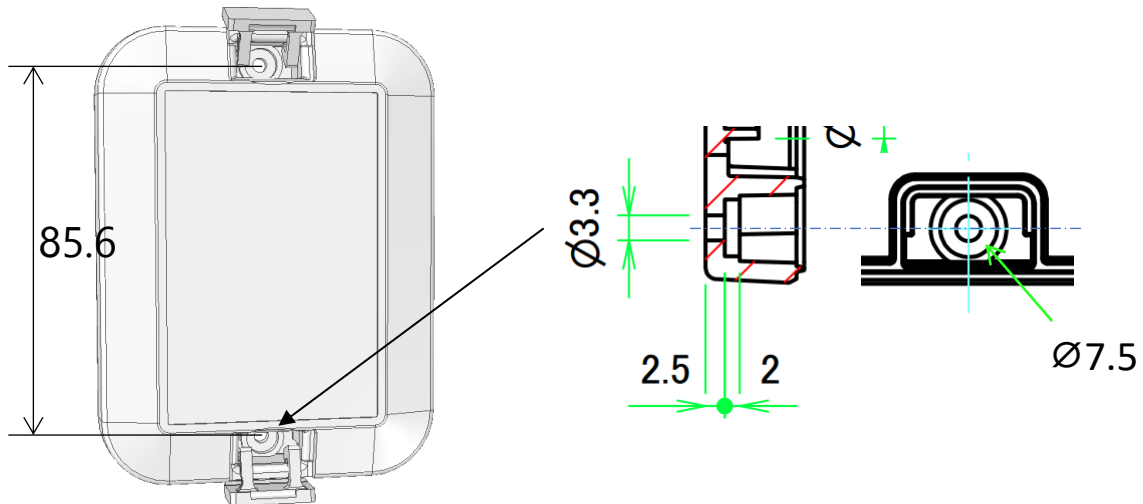


Figure 8: Mounting holes

It can also be mounted using straps and accessories (WPMB-M3):



Figure 9: Pole mounting

This accessory is not included per default within our product. It can however be ordered directly through our casing manufacturer.

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4.4 Stickers

An example is presented below:

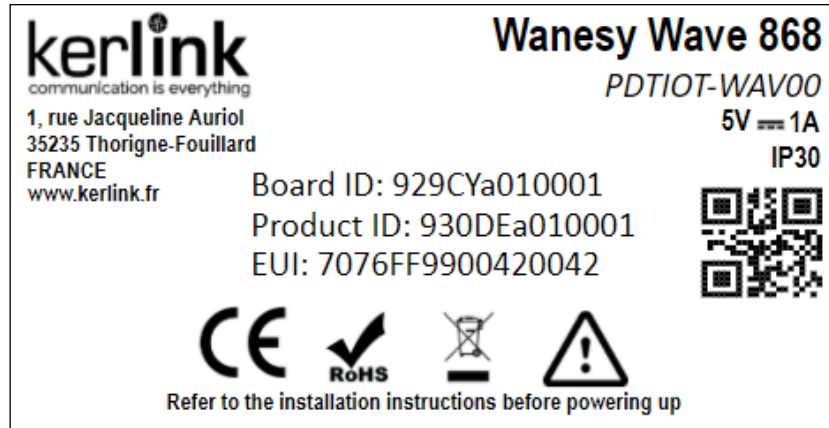


Figure 10: Labels

5. Software architecture

5.1 Block diagram

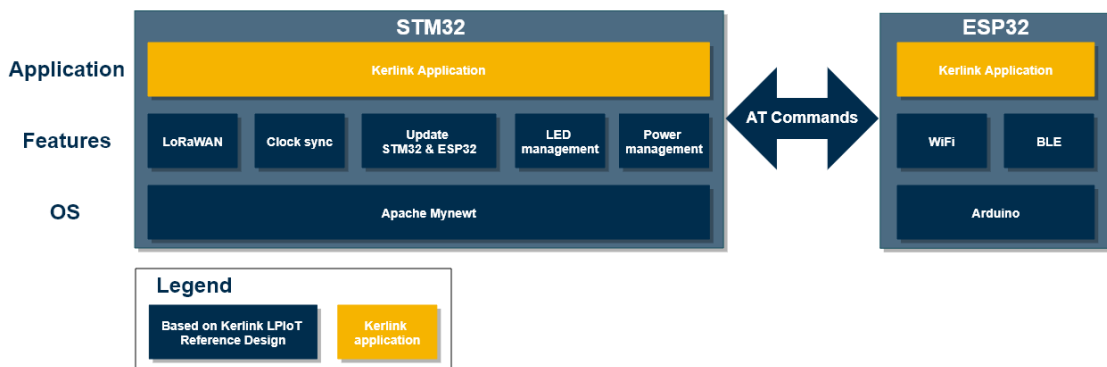


Figure 11: Software architecture

5.2 Core Layer

5.2.1 Operating system

5.2.1.1 STM32

The OS used on Wanesy™ Wave STM32 is the Apache MyNewt Operating System. MyNewt is a modular real-time operating system designed for the IoT developed by Apache Software Foundation.

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This OS is a free and open-source software distributed under the Apache License 2.0. The current version used is 1.3.0 (up to date). Regular update will be done on the Wanesy Wave to match with the newest MyNewt release.

This OS allows the use of:

- Preemptive scheduler (multithreading)
- Mutexes
- Semaphores
- Programmable soft timer
- Threads
- Message Queues.

5.2.1.2 ESP32

The Operating system used on the ESP32 is Arduino.

5.2.2 Network stacks

5.2.2.1 LoRaWAN

Wanesy™ Wave is compatible with the LoRaWAN™ Specification V1.0.2 and the regional parameters EU868 and US915MHz. All classes (A / B / C) are supported.

The implementation is based on the LoRaMac-Node stack from Semtech/Stackforce, driven by the Kerlink's lorawan_api package.

5.3 Services

5.3.1 Scheduler

The scheduler mechanism of Wanesy™ Wave includes:

- Alarm mode to wake up the OS after a defined delay.
- Calendar mode to wake up the OS at a defined date time.

5.3.2 Power management

The power management mechanism included in Wanesy™ Wave provide services to reduce the consumption of the overall product in order to optimize the customer's product lifetime.

5.3.3 Secure bootloader

Wanesy Wave provides the MCUBoot [3] secure bootloader

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5.4 Application

5.4.1 Wi-Fi Probe Request Count

The ESP32 manages the collect of the Wi-Fi probe request in list and manage counters. A result message is sent to STM32 for LoRaWAN protocol communication

5.4.2 BLE Scan

The ESP32 manages SCAN BLE of iBeacon and send result message to STM32.

5.4.3 Wave Application

5.4.3.1 Behavior of the product when connected to the power supply

When the product is powered supplied, the product can use all the features available on the product:

- Wi-Fi Probe Request Count
- Wi-Fi Access Point
- BLE scan iBeacon
- LoRaWAN transmissions for BLE scan result and WIFI Count

The ESP32 application must be able to enable/disable each feature depending on the configuration saved in the ESP32. If a feature is enabled, the application must also initialize the feature also based on the configuration.

5.4.3.2 Behavior of the product when disconnected from the power supply

When the product is disconnected from the power supply, for power optimization, it must enter a low consumption state which forces to stop (power off) all available features.

In this low consumption, the ESP32 is powered off and the STM32 must remain in deep sleep and wakes up periodically to send LoRaWAN frames to the network. The period of emission of the LoRaWAN is hardcoded in the firmware.

5.4.4 Led Behavior

The Two LEDs (Green & Red) are providing information on the functioning of the device. To optimize the backup battery usage, the LEDs are only used when the product is power supplied.

5.4.4.1 Green LED

- **Blinking** (ON = 200ms | OFF = 1s): During the initialization process:
 - Join accept received
 - ESP32 successfully initialized
- **ON**: After initialization
- **OFF**: When the product is not power supplied

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5.4.4.2 Red LED

- **ON:** LoRaWAN operation in progress (TX/RX).
- **OFF:** No LoRaWAN operation in progress.

5.5 LoRaWAN

The LoRaWAN configuration is hardcoded in the firmware. Some LoRaWAN parameters can be modified using LoRaWAN Mac messages. More information is available in the LoRaWAN specification. LoRaWAN ADR mode is activated and no default DR is 2 in EU868 band.

5.5.1 Message uplink frame format for WIFI COUNT

Uplink LoRaWAN message concerning WIFI COUNT is sent in FPort: 80
Detail of uplink WIFI COUNT LoRaWAN message is in the COUNT Protocol Annex.

5.5.2 Message uplink frame format for BLE SCAN

Uplink LoRaWAN message concerning BLE_SCAN is sent in FPort: 85
Detail of uplink BLE SCAN LoRaWAN message is in the CBOR Protocol Annex.

5.5.3 Behavior in case of LoRaWAN emission not acknowledged

If a LoRaWAN frame is not acknowledged without retry mechanism. The number of retries is hardcoded in the firmware (equal to 3).

5.6 Exchange protocol between ESP32 and STM32

5.6.1 AT Protocol

The communication protocol between the ESP32 and STM32 is maintained by a bi-directional protocol on the UART physical layer. The protocol is inspired by AT Commands from 3GPP specifications.

A definition of the documentation is available in the AT protocol Annex.
Exchange AT command process is described in LoRaWAN exchanges Annex.

5.6.2 CBOR Protocol for BLE SCAN result

The data BLE SCAN sent by the ESP32 to the STM32 is encoded using the CBOR protocol.
CBOR frames are sent to LoRaWAN protocol in a second step.

Documentation to process specifically BLE scan result is available in the CBOR Protocol Annex.
Annex part is used by customer to decode data received by LoRaWAN

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5.6.3 COUNT Protocol

The data for WIFI COUNT sent by the ESP32 to the STM32 is encoded using the WIFI COUNT protocol. An extraction of the documentation specifically for BLE scan is available in the COUNT Protocol Annex.

5.7 Over the air update

5.7.1 LoRaWAN

The reception of files (firmware or other) over the air on the Wave product must be done using the FUOTA (Firmware Update Over The Air) as described by the LoRa Alliance

That feature is currently under development. More information will be detailed here once released.

5.7.2 Wi-Fi

That feature is currently under development. More information will be detailed here once released.

5.8 Remote configuration

All parameters re-configured describe in this chapter are automatically saving and restoring after product restarted.

5.8.1 ESP32 application reconfiguration

Remote configuration is done using the LoRaWAN downlink messages. The strategy used for the Wave product is the transmission of AT command using the format defined in the AT protocol.

The STM32 will automatically forward the commands to the ESP32.

Answers to the commands must be forwarded to the server using LoRaWAN uplink messages.

The LoRaWAN fport used for the uplink/downlink messages for AT command is: **65**

- 1- **Wi-Fi device RSSI threshold:** AT command used to limit WIFI COUNT device with RSSI value higher than define threshold
(Reference to chapter 1.3.3.2)

Payload text: (AT command)

AT+WPR/TH=-XX with -XX is RSSI threshold

⇒ Only Wi-Fi counter with RSSI higher than -XX

If XX is equal to 0, the threshold is removing and no RSSI filter appli

More detail in AT+WPR/TH command annex

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- 2- **BLE SCAN major list:** AT command to program a major list of BLE iBeacon will be scan. If iBeacon of major different of list, it won't be selected.

Payload text: (AT command)

AT+BLE/MLIST=XX,YYY,... with XX and YYY is major value in Decimal (value from 0 to 65534)

When AT command is received by ESP32, only BLE iBeacon of major equal to one of listing major will be detected during scan.

Major value 0xFFFF is forbidden in the system, only value from 0 to 0xFFFE is available.

Maximum of 10 majors parameter can be enter in the list.

Each AT command "BLE/MLIST", previous list is removed

If no XX and yy (AT+BLE/MLIST=), List is removed and BLE scan accept all iBeacon

More detail in AT+BLE/MLIST command annex

- 3- **BLE SCAN confirm message delay:** AT command used to confirm BLE iBeacon if it is remained detected during scan.

Payload text: (AT command)

AT+BLE/CNF=XX with XX is time in second

When AT command is received by ESP32, BLE iBeacon is confirm by message if it is detected for XX seconds.

If XX is not present or equal to 0, the parameter comes back to default value: 300s

More detail in AT+BLE/CNF command annex

- 4- **BLE SCAN RSSI filter threshold:** AT command used to fix RSSI threshold to filter BLE iBeacon during scan.

Payload text: (AT command)

AT+BLE/RSSI=XX,YY with

XX is RSSI level threshold (between -1 and -94)

YY is RSSI level hysteresis to exit BLE scan (between 0 and -20)

When AT command is received by ESP32, only TAG BLE with RSSI level upper than XX is collected.

Only tag BLE already collected would be exit if RSSI I lower than XX+YY

If AT command send with XX is equal to 0, the parameter comes back without filter

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More detail in AT+BLE/RSSI command annex

5.8.2 STM32 Application reconfiguration and Basic device Management

The LoRaWAN fport used for the downlink message to reboot is: **68**

Payload: The first byte is the command, and following bytes (optional) are the data of the command

List of command:

0x00: test command - no effect (test response only)

0x01: reboot command – with the data [0x62, 0x6F, 0x6F, 0x74], the end-device will reboot after 10 seconds

0x02: format FileSystem command – with the data [0x66, 0x6F, 0x72, 0x6d, 0x61, 0x74], the end-device will format Filme system

0x10: Wifi count application reconfigure. Payload respect following structure:

```
Typedef struct {
    uint32_t period_sec_cfg ;
    uint32_t counter_max;
    uint32_t clock_sync_period ;
} s_cnt_rx_payload_t ;
```

Example:

Downling payload: 022C010000E803000008070000
period_sec_cfg = 300 secondes (5mn)

counter_max = 1000
clock_sync_period = 1800 (30mn)

Default configuration of WiFi Probe Request Count are:

period_sec_cfg = 15mn (900s)

Max counter wifi to send frame (before period_sec delay) counter_max = 2000

clock sync period clock_sync_period = 60mn (3600s)

0x11: BLE scan application reconfigure. Payload respect following structure:

```
Typedef struct {
    uint32_t scan_delay ;
    uint32_t scan_timeout;
} s_ble_scan_rx_payload_t ;
```

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Example:

Downling payload: 03780000000C000000
 scan_delay = 120 secondes (2mn)
 scan_timeout = 12 secondes

Default configuration of WiFi BLE SCAN Count are:

scan_delay = 60s (1mn)
 scan_timeout = 10s

Others: reserved for future use

6. Certification

6.1 FCC

The Wanesy Wave product is compliant with standard certification requirements for FCC Marking.

6.2 CE

The Wanesy Wave product is compliant with standard certification requirements for CE Marking.

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ANNEX

7. AT protocol

The AT protocol documentation is extracted from the Low Power IoT Reference Design documentation (conversion done using pandoc)
(SHA1: 83c84965908d69624788992da10745ee43d065f2)

Note: “x.y” version means not implemented yet.

7.1 Physical settings

Currently, the described protocol is bi-directional, and uses an UART as a physical layer. The following parameters should be used:

Parameter	Value
Speed (Bps)	115200
Parity	None
Data	8
Stopbits	1
Hardware Flow Control	No
Software Flow Control	No

7.2 Protocol description

The protocol is inspired by AT commands: it is fully described on the following section.

7.2.1 AT commands syntax

7.2.1.1 Abbreviations

Symbol	Meaning
<CR>	Carriage return character
<LF>	Line Feed character
<...>	Name enclosed in angle brackets is a syntactical element. Brackets themselves do not appear in the command line.

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[...] Optional subparameter of a command. Brackets themselves do not appear in the command line.

7.2.1.2 Simple command

Simple command syntax:

- AT+CMD0<CR>

Simple answer syntax:

- <CR><LF>OK<CR><LF>
- <CR><LF>ERROR<CR><LF>

7.2.1.3 Read command

Read command for checking current subparameter values syntax:

- AT+CMD1?<CR>

Associated response syntax:

- <CR><LF>+CMD1: <subparameter1>,<subparameter2>,... <CR><LF>

7.2.1.4 Command with subparameter

Command with subparameter syntax:

- AT+CMD2=<subparameter1>,<subparameter2><CR>

7.2.2 Technical table

Name **Meaning**

State | State of the feature:

- ON: enable the feature
- OFF: disable the feature

RAW data | Raw data

Format: HEXASCII

CBOR data | Data, CBOR formatted

Format: HEXASCII

URL | Relative URL (can be "404" for undefined URLs)

Format: ASCII

Web Content | Web page source content

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Format: ASCII

RSSI Threshold | RSSI Threshold: under this threshold, collected messages are discarded. Use 0 to disable this filter. Value from -94 to -1

Format: Integer

MAC | MAC Address

Format: HEXASCII 48bit

MaxFrameSize | Maximum frame size allowed in data responses

Format: Integer

SSID | SSID WiFi Access Point

Format: ASCII

Key | Password WiFi Access Point (can be void)

Format: HEXASCII

Channel | Channel WiFi Access Point (can be void for 'auto')

Format: Integer

BLE Period | BLE period that schedules each beacon transmission

Format: Integer

BLE Content | BLE beacon raw content that is sent on each transmission

Format: HEXASCII

Data mode | Set the Data Mode that will be used (see [AT+DATA](#) for details)

Format: Integer

Time | Current time in seconds, aligned on the GPS epoch

Format: Integer |

7.2.3 Basic AT commands

Command	Meaning
AT	Basic AT test command
+V	Get software and hardware versions
+F	Reset Factory Modem + Reboot

7.2.4 WiFi Access Point AT commands

Command	Meaning
+WAP/EN	Manage the WiFi Access Point feature
+WAP/SSID	Manage the WiFi Access Point settings

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[+WAP/WWW](#) Manage the WiFi Access Point webserver

7.2.5 WiFi Probe Request Collector AT commands

Command	Meaning
+WPR/EN	Manage the WiFi Probe Request Collector feature
+WPR/TH	Manage the WiFi Probe Request Collector RSSI Threshold
+WPR/BLIST	Manage the WiFi Probe Request Collector Blacklist

7.2.6 Bluetooth AT commands

Command	Meaning
+BLE/EN	Manage the BLE feature
+BLE/BEA	Manage the BLE Beacon settings
+BLE/MLIST	Manage BLE Scan “major” list
+BLE/CNF	Delay of confirmation presence of iBeacon
+BLE/RSSI	RSSI Level Threshold and Hysteresis

7.2.7 Data management AT commands

Command	Meaning
+DATA	Manage the data link with the WiFi/BLE chip
+TIME	Set the time on the WiFi/BLE chip
+COUNT	Start count mode with max value

7.2.8 Data responses

Command	Meaning
+RAWDATA	Raw data buffer
+CBOR	Data buffer, CBOR formatted
+COUNT	Data buffer, binary format

7.3 Details of AT commands

7.3.1 Basic AT commands details

7.3.1.1 AT

AT	Basic AT command	1.0
Command	AT	
Response	OK	

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7.3.1.2 +V

+V Get versions command 1.0

Command AT+V?

Response +V: <software version>,<hardware version> OK / ERROR

7.3.1.3 +F

+F Reset Factory Modem + Reboot 1.0

Command AT+F

Response OK/ERROR

7.3.2 WiFi Access Point AT commands details

7.3.2.1 +WAP/EN

+WAP/EN Enable / Disable the WiFi Access Point feature 1.0

Command AT+WAP/EN=<[state](#)>

Response OK/ERROR

7.3.2.2 +WAP/SSID

+WAP/SSID Create / Modify a WiFi Access Point x.y

Command AT+WAP/SSID=<[SSID](#)>,<[Key](#)>,<[Channel](#)>

Response OK/ERROR

Note: In the x.y version, only one Access Point is configurable.

7.3.2.3 +WAP/WWW

+WAP/WWW Create / Modify a webpage served on an URL x.y

Command AT+WAP/WWW=<[URL](#)>,<[Content](#)>

Response OK/ERROR

Note: if content is empty, the webpage is deleted.

7.3.3 WiFi Probe Request Collector AT commands details

7.3.3.1 +WPR/EN

+WPR/EN Enable / Disable the WiFi Probe Request Collector feature 1.0

Command AT+WPR/EN=<[state](#)>

Response OK/ERROR

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7.3.3.2 +WPR/TH

+WPR/TH Manage the WiFi Probe Request Collector RSSI Threshold filter 1.1

Command AT+WPR/TH=<[RSSI Threshold](#)>

Response OK/ERROR

7.3.3.3 +WPR/BLIST

+WPR/BLIST Manage the WiFi Probe Request Collector Blacklist filter x.y

Command AT+WPR/BLIST=<[MAC1](#)>,<[MAC2](#)>,<[MACn](#)>

Response OK/ERROR

7.3.4 Bluetooth AT commands details

7.3.4.1 +BLE/EN

+BLE/EN	Enable / Disable the Bluetooth feature	1.0
Command	AT+BLE/EN=< state >,<timeout>	
Parameter	timeout: timeout of BLE Scan. If parameter not present, default timeout parameter value (20 seconds)	
Response	OK/ERROR	

7.3.4.2 +BLE/BEA

+BLE/BEA	Manage Bluetooth Beacon format	x.y
Command	AT+BLE/BEA=< Period >,< Content >	
Response	OK/ERROR	

7.3.4.3 +BLE/MLIST

+BLE/MLIST	Manage BLE Scan "Major" list	x.y
Command	AT+BLE/MLIST=<MAJOR1>,<MAJOR2>,<MAJORn>,...	
Parameter	MAJORn: major parameter of iBeacon to filter on it. Each AT command BLE/MLIST remove the previous one Max.: 10 majors maximum in list If No major in parameter ("AT+BLE/MLIST="), major list is removing.	

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Response OK/ERROR

7.3.4.4 +BLE/CNF

+BLE/CNF **Delay of confirmation presence of iBeacon** **x.y**

Command AT+BLE/CNF=<delay>

Parameter **delay:** delay of confirmation message if one iBeacon is always detected

If No delay parameter or delay = 0 (“AT+BLE/CNF=” or “AT+BLE/CNF=0”), delay is equal to default value (**310 seconds**).

Response OK/ERROR

7.3.4.5 +BLE/RSSI

+BLE/RSSI **RSSI Level Threshold and Hysteresis** **x.y**

Command AT+BLE/RSSI=<threshold>,<hysteresis>

Parameter **threshold:** RSSI level threshold (between -1 and -94)
hysteresis: RSSI level hysteresis to exit BLE scan (between 0 and -20)

If threshold = 0 (“AT+BLE/RSSI=0”), RSSI filter is removed.

Response OK/ERROR

7.3.5 Data configuration

7.3.5.1 +DATA

+DATA **Manage the data link with the WiFi/BLE chip**

1.1

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Command AT+DATA=<[MaxFrameSize](#)>,<[DataMode](#)>,<Timeout>

Parameter **MaxFrameSize**: each data packet ([+RAWDATA](#), [+CBOR](#) or [+COUNT](#)) will not exceed the MaxFrameSize. Valid values for this range are from 21 to 255 bytes (both included).

DataM

ode: choose the data strategy according to the host capabilities:

- **0**: Realtime mode: as soon as data are ready, they are sent to the host continuously (timeout is not used).
- **1**: One-by-one mode: only one data will be sent to the host. The host shall send again the AT+DATA command when it is ready in order to wait the next data (timeout is not used).
- **2**: Realtime + Timeout mode: same as Realtime mode, with a maximal timeout trigger which can produce an empty payload even if there is no data (implemented in x.y)
- **3**: One-by-one + Timeout mode: same as One-by-one mode, with a maximal timeout trigger which can produce an empty payload even if there is no data (implemented in x.y)

Response OK/ERROR

7.3.5.2 +TIME

+TIME	Set the time on the WiFi/BLE chip	1.1
Command	AT+TIME=<Time>	
Response	OK/ERROR	

7.3.5.3 +COUNT

+COUNT	Start count mode with max value	1.1
Command	AT+COUNT=<Count>	
Parameter	Count : Value of max number of count. Not used	
Response	OK/ERROR	

7.3.6 WiFi/BLE chip responses

7.3.6.1 +RAWDATA

Data buffer sent from the WiFi/BLE chip to the host, without defined

+DATA **format** **x.y**

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Response +RAWDATA=<[raw data](#)>

7.3.6.2 +CBOR

+CBOR Data buffer sent from the WiFi/BLE chip to the host, CBOR formatted **1.0**

Response +CBOR=<[CBOR](#)>

7.3.6.3 +COUNT

+COUNT Data buffer sent from the WiFi count to the host, Specific format frame **1.0**

Response +COUNT=<binary>

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8. CBOR Protocol

CBOR protocol is based on chapter WiFi/BLE chip responses +CBOR on link [+CBOR response](#) for exchange from ESP32 to STM32

8.1 Presentation

When BLE scan sends data through the response "+CBOR=xxxxxx", the payload is transmitted in hexascii mode with a CBOR representation.

CBOR is a binary data serialization, close to a JSON representation. The transmission of data object contains key-values pair: by definition, the sender and the receiver must agree on the interpretation of these key-values pairs, but it will not break the compatibility if other pairs are added later.

8.2 BLE Scan use-case

One of the features of the BLE SCAN is to collect near BLE iBeacon. iBeacons collected during scan will be forwarded to a server in order to analyze them.

New iBeacon identification in this version to add major parameter and optimize the send

To be usable by the server, a caught BLE iBeacon must contain:

- MAJOR+MINOR iBeacon param (4 bytes data – 2 MSB Major and 2 LSB minor)
- RSSI level

8.2.1 Format

Here is the description of the format used:

- a key "t" is used to indicate the absolute timestamp (GPS epoch) of the end of BLE Scan.
- a key "n" is used to store an array of new BLE identify from previous scan. Each data is composed of: MAJOR+MINOR iBeacon param + RSSI.
- a key "c" is used to store an array of confirmation of BLE identify after a delay of presence. Each data is composed of: MAJOR+MINOR iBeacon param + RSSI.
- a key "r" is used to store an array of not detected BLE identify from previous scan. Each data is composed of: MAJOR+MINOR iBeacon param.

In order to be more efficient, each data field is optimized, and described in following sections.

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8.2.1.1 DATA on format

The first entry in the table is a MAJOR+MINOR (between 1 to 5 bytes in CBOR mode). Optimization with the previous value of MAJOR MINOR parameter is done.

“type” parameter (1 bytes) is removed in this version and just one structure of data BLE tag identification for each format.

For ‘n’ and ‘c’ format:

- Array of 3 parameters: MAJOR+MINOR iBeacon param, RSSI and Moving/Status.

For ‘r’ format:

- MAJOR+MINOR iBEACON param (no array)

8.2.1.2 MAJOR+MINOR iBeacon parameter

Entry in the table is a 4 bytes with MAJOR in MSB (2 Bytes) + MINOR in LSB (2 bytes).

Each couple MAJOR+MINOR param is filter by ascending value.

An optimization is done for the second and the following iBeacon MAJOR+MINOR for one specific format (‘c’, ‘r’ and ‘r’) with only the delta.

BLE tag mustn’t have major and minor equal to 0xFFFF(65535), unavailable tag BLE values.

Example:

- 0x08020245 => Major is 0x802 (2050 in decimal) and Minor is 0x245 (591 in decimal)
- If a second element in the same format is 0x08030102 (Major 0x803 and minor 0x102) the value of MAJOR+MINOR parameter will be 0xFEED (equal to 0x08030102 - 0x08020245)

8.2.1.3 RSSI optimization

All RSSI measurements have a negative value included in the range [0;-94]. In order to be more efficient on the CBOR encoding, we apply the following algorithm on the RSSI value:

$$(\text{RSSI} + 47) / 2 = \text{enc_RSSI}$$

8.2.1.4 Moving/Status

A Moving/Status is information of device move or not (and reserved bits). The value is 0 if not move and 1 if move.

DEAR Beacon E9 BLE tag of MINEW company is selected to detect moving by accelerometer.

If change state from moving to not moving and invert, a BLE tag Major / Minor information is sent in type with key confirm “c”

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8.2.1.5 Example

Let's take a BLE scan capture example:

BLE Scan (n-1): Previous tab:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move
10	2048 (0x800)	3056 (0xBF0)	-52	0
10	2048 (0x800)	3057 (0xBF1)	-64	0
10	2048 (0x800)	18069 (0x4695)	-88	0
10	2049 (0x801)	45 (0x2D)	-41	0

New BLE Scan (n): Tab

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move
60	2047 (0x7FF)	3 (0x3)	-56	1
60	2048 (0x800)	3056 (0xBF0)	-50	0
60	2048 (0x800)	3057 (0xBF1)	-80	0
60	2048 (0x800)	25024 (0x61DE)	-40	0

The new tab with complete STATUS of each iBeacon:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move	Status
60	2047 (0x7FF)	3 (0x3)	-56	1	New
60	2048 (0x800)	3056 (0xBF0)	-50	0	Confirm
60	2048 (0x800)	3057 (0xBF1)	-80	0	Confirm
10	2048 (0x800)	18069 (0x4695)	-88	0	Remove
60	2048 (0x800)	25024 (0x61DE)	-40	0	New
10	2049 (0x801)	45 (0x2D)	-41	0	Remove

The new tab with RSSI optimization in each iBeacon not removed:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move	Status
60	2047 (0x7FF)	3 (0x3)	-4	1	New
60	2048 (0x800)	3056 (0xBF0)	-1	0	Confirm
60	2048 (0x800)	3057 (0xBF1)	-16	0	Confirm
10	2048 (0x800)	18069 (0x4695)	Not used	Not used	Remove
60	2048 (0x800)	25024 (0x61DE)	+3	0	New
10	2049 (0x801)	45 (0x2D)	Not used	Not used	Remove

The same dataset is put in 3 specifics formats (“new”, “confirm”, “remove”) with timestamp:

```
{t=60,
“n”, [[0x7FF0003, -4, 1],
      [0x161DB, 3, 0]],
“r”, [ 0x8004695, 0xB998]],
“c”, [[0x8000BF0, -1, 0],
      [0x1, -16, 0]]}

{"t": 60,
"n": [[0x7FF0003, -4, 1], [0x161DB, 3, 0]],
"r": [0x8004695, 0xB998],
"c": [[0x8000BF0, -1, 0], [0x1, -16, 0]]}
```

The same with decimal value decimal value:

```
{"t": 60,
"n": [[134152195, -4, 1], [90587, 3, 0]],
"r": [134235797, 47512],
"c": [[134220784, -1, 0], [1, -16, 0]]}
```

The CBOR representation is the following:

```
BF6174183C616E82831A07FF00032301831A000161DB03006172821A0800469519B998616
382831A08000BF0200083012F00FF
```

The online tool cbor.me can be used to decode the payload.

8.2.1.6 Example Move change

Let's take a BLE scan capture example:

BLE Scan (n-1): Previous tab:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move
10	2048 (0x800)	3056 (0xBF0)	-52	0
10	2048 (0x800)	3057 (0xBF1)	-64	0
10	2048 (0x800)	18069 (0x4695)	-88	0
10	2049 (0x801)	45 (0x2D)	-41	0

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New BLE Scan (n): Tab

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move
60	2048 (0x800)	3056 (0xBF0)	-52	0
60	2048 (0x800)	3057 (0xBF1)	-64	1
60	2048 (0x800)	18069 (0x4695)	-88	0
60	2049 (0x801)	45 (0x2D)	-41	0

The new tab with complete STATUS of each iBeacon:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move	Status
60	2048 (0x800)	3056 (0xBF0)	-50	0	Not sent
60	2048 (0x800)	3057 (0xBF1)	-80	1	Confirm
60	2048 (0x800)	18069 (0x4695)	-88	0	Not sent
60	2049 (0x801)	45 (0x2D)	-41	0	Not sent

The new tab with RSSI optimization in each iBeacon not removed:

Timestamp	BLE MAJOR	BLE MINOR	RSSI	Move	Status
60	2048 (0x800)	3056 (0xBF0)	-50	0	Not sent
60	2048 (0x800)	3057 (0xBF1)	-16	1	Confirm
60	2048 (0x800)	18069 (0x4695)	-88	0	Not sent
60	2049 (0x801)	45 (0x2D)	-41	0	Not sent

The same dataset is put in 3 specifics formats ("new","confirm","remove") with timestamp:

```
{t=60,
"c",[[0x8000BF1,-1,1]]}
```

The same with decimal value decimal value:

```
{"t": 60,
"c": [[134220784, -1,1]]}
```

The CBOR representation is the following:

```
A26174183C616381831A08000BF02001
```

The online tool cbor.me can be used to decode the payload.

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9. COUNT Protocol

Count protocol is based on chapter WiFi/BLE chip responses +COUNT on link [+COUNT response](#) for exchange from ESP32 to STM32

The following data format is reference of data sent by LoRaWAN protocol.
The data format of data uplink sent have the following format:

```
Typedef struct {
    uint32_t period_sec;
    uint32_t counter;
    uint16_t rssi_tab[10];

    uint16_t counter_new;
    uint16_t counter_remove;
} s_cnt_tx_payload_t;
```

period_sec: Period in second of probe request collected.

counter: Number of different MAC address by probe request collect

Rssi_tab are composed of 10 Wifi counter value (in 2 bytes each) with threshold RSSI interval that following

RSSI value is included in interval 0 to -100 dbm

Index 0 => number of wifi collect with rssi between 0 to -9dbm

Index 1 => number of wifi collect with rssi include -10dbm to -19dbm

....

counter_new: Number of new MAC address compared to previous probe request collect

counter_remove: Number of remove MAC address compared to previous probe request collect

Example payload uplink:

840300004E020000010002000500110022005400230004017000280062004300

⇒ Collect period is 900s (0x00000384)

⇒ Number of Wi-Fi collect is 590 (0x0000024E)*

Index	Rssi interval	Rssi[i]
0	[0, -9]	1 (0x0001)
1	[-10, -19]	2 (0x0002)
2	[-20, -29]	5 (0x0005)
3	[-30, 39]	17 (0x0011)
4	[-40, -49]	34 (0x0022)
5	[-50, -59]	84 (0x0054)
6	[-60, -69]	35 (0x0023)

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7	[-70, -79]	260 (0x0104)
8	[-80, -89]	112 (0x0070)
9	[-90, -100]	40 (0x0028)

- ⇒ Number of new MAC address with previous collect is 98 (0x0062)
- ⇒ Number of remove MAC address with previous collect is 67 (0x0043)

10. LoRaWAN exchanges

Several LoRaWAN FPort are used on the application layer. Here is the description of the usage of these FPorts.

10.1 AT commands bridge

FPort: 65

Payload: the full AT command which will be transfer untouched to the ESP32

Description: To send an AT command to the ESP32, the buffer can be sent on the FPort 65 and the STM32 will transfer the buffer to the ESP32. The response of the ESP32 (data + OK/ERROR) is encapsulated into the next LoRaWAN Uplink on the same FPort (65). If an error occurs, the FPort used will be the 66.

End of document

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