



life.augmented



STDES – CBMLoRaBLE

System solution for IIoT applications with
Multi Connectivity and Multi Sensors

V1.0

Jun 2023

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STDES-CBMLoRaBLE: Application Overview



Industrial IoT Application Scenarios



Smart Building & Infrastructure
Structural Health Monitoring (**SHM**)



Smart Farm
Condition Based Monitoring (**CBM**)



Smart Industry
Condition based Monitoring (**CBM**)



Telecom
Pointing, levelling and stabilization(**SHM**)



IIoT enabling different smart applications

Architecture Issue

- ❑ The **Industrial IoT (IIoT)** is recently gaining acceptance also in industrial fields that operate in remote areas, with harsh environmental conditions and low connection capability, like: **Oil & Gas, Mining, Wind & Photovoltaic Farm and Large Infrastructure monitoring.**
- ❑ The key elements are smart sensor nodes, able to handle several measurements, with embedded processing, and able to send the data results on the network, in secure way.
- ❑ An **IIoT** architecture leverages complex monitoring systems with multiple nodes and gateways that often present cabling issues over short and long ranges.
- ❑ A wireless technologies, could be a good alternative, flexible and scalable to extend the coverage area, without limits for distances, with long battery lifetime, and low bitrate.
- ❑ The **STDES-CBMLoRaBLE** proposes an innovative modular system platform, based on:
 - ❖ Multiple Sensors for vibration, inclination, environmental, acoustic and presence detection.
 - ❖ Multiple wireless connectivity, Short - Long Range, to address many industrial scenarios with different conditions and several needs.

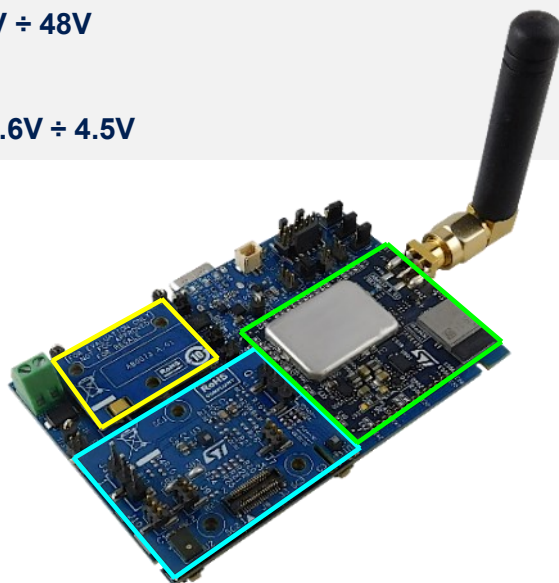


STDES-CBMLoRaBLE: Multi connectivity platform overview



System Platform for IIoT platform with
Multi Connectivity and Multi Sensors

- ❑ **Connectivities** → **SHORT** (2.4GHz BLE) & **LONG** (Sub-1GHz LoRa)
- ❑ **Sensors Expansion board:**
 - EXP1: Vibration, Dynamic Inclinator, Accelerometer, Temperature
 - EXP2: Microphone, Pressure and Temperature
- ❑ **Three main power supply**
 - Industrial bus → 12V ÷ 48V
 - USB type C → 5V
 - Primary Battery → 3.6V ÷ 4.5V



Processing &
Security



Long &
Short-range
Connectivity



Power management
& Protections



External Modules for
MEMS Sensors



STM32WB



216 CoreMark
64 MHz

STM32WL



162 CoreMark
48 MHz

STSAFE A110



L7983

TCP01

ESDALC6V1

ESDA25P35

USBL6-2P6

ESDA7P120

ST1PS02



IIS3DWB
(3D Vibrometer)



IIS2ICLX
(2D + MLC)



ISM330DHCX
(3D+3D+ MLC)



STTS22H



IMP34DT05A



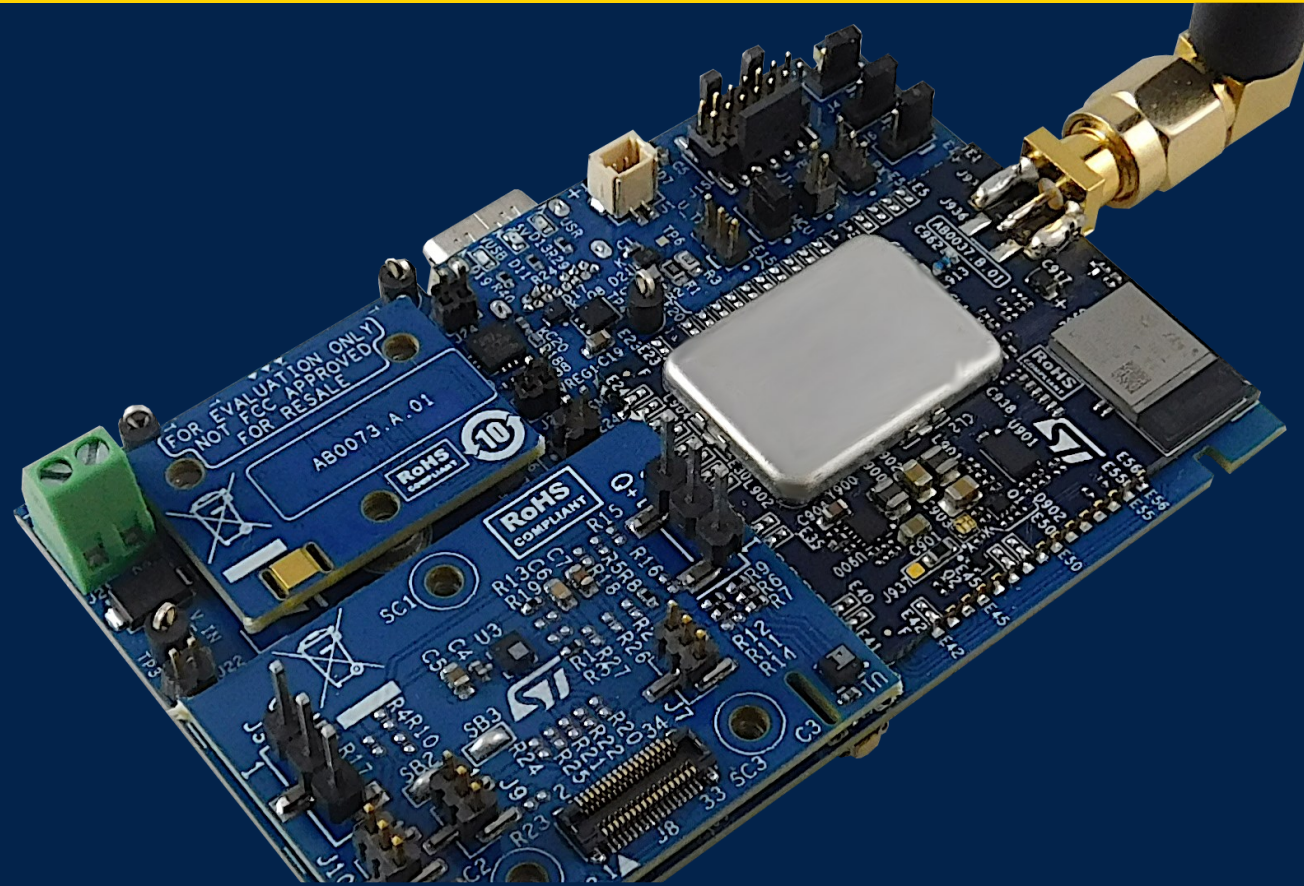
ILPS22QS



EXP1

EXP2

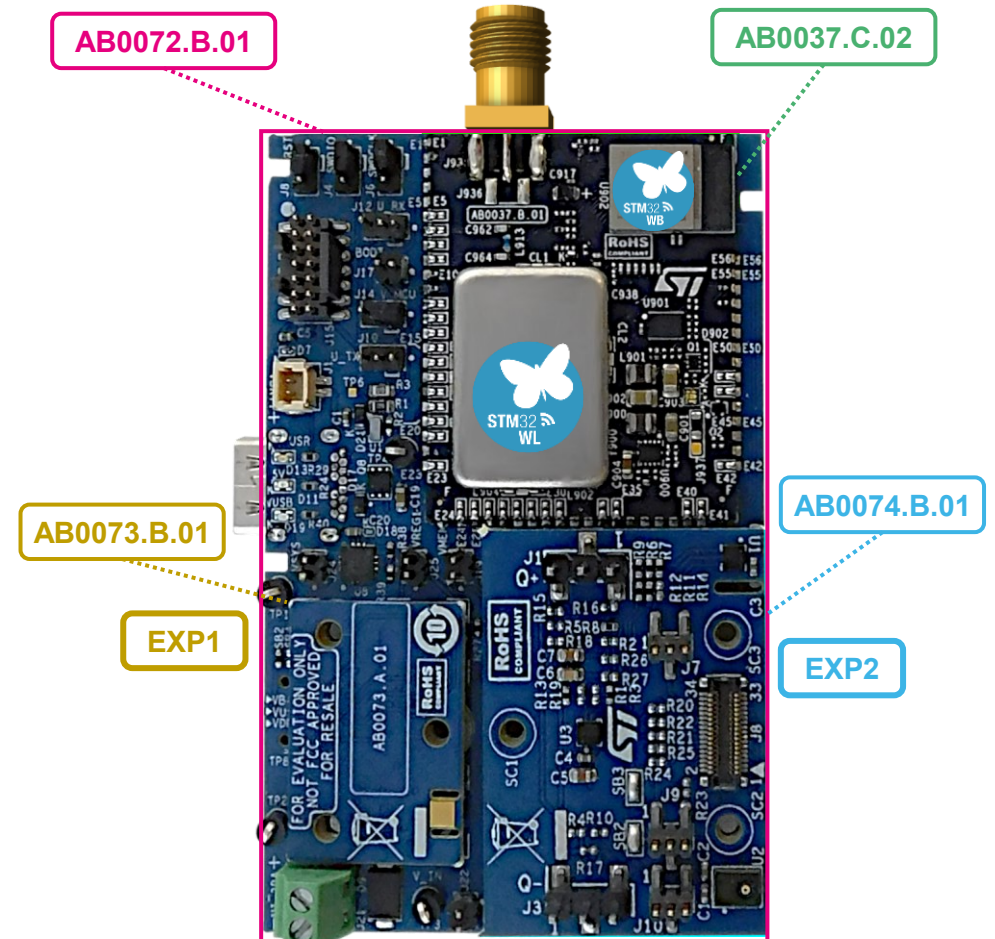
STDES-CBMLoRaBLE: Hardware Description



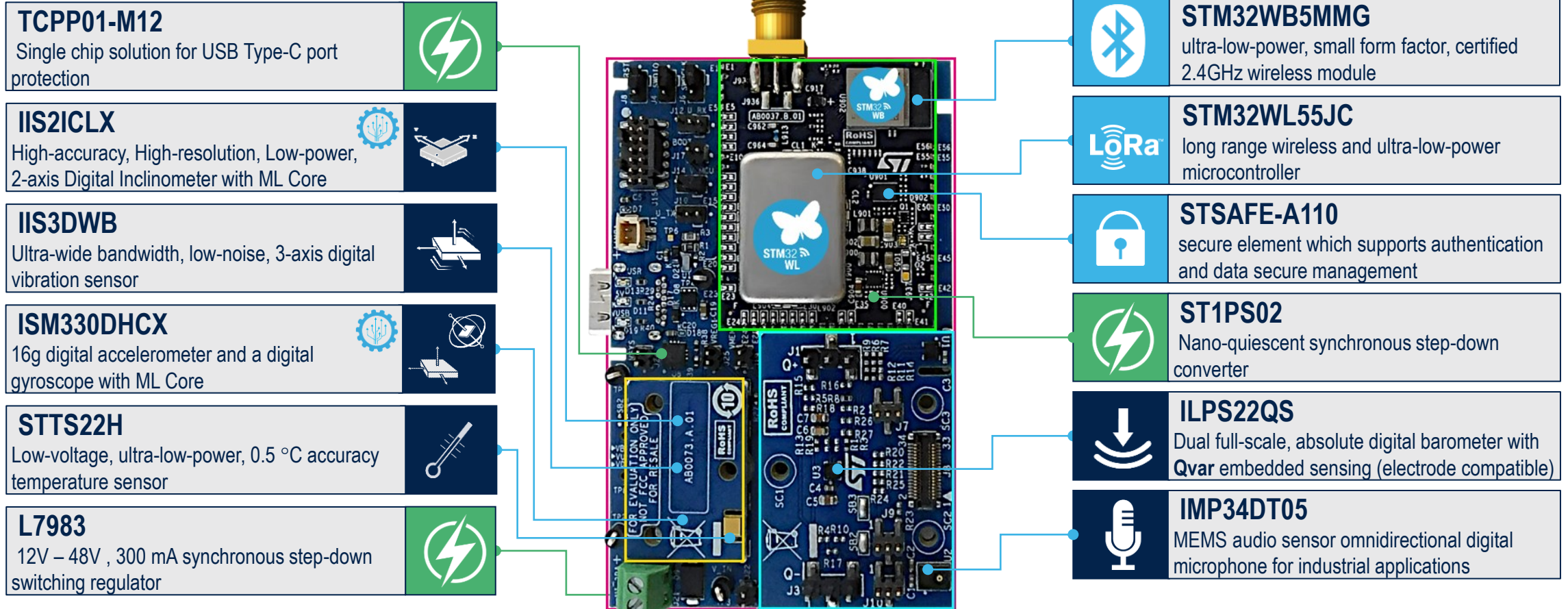
STDES-CBMLoRaBLE: Hardware description

STDES-CBMLoRaBLE: IIoT platform based on a modular approach

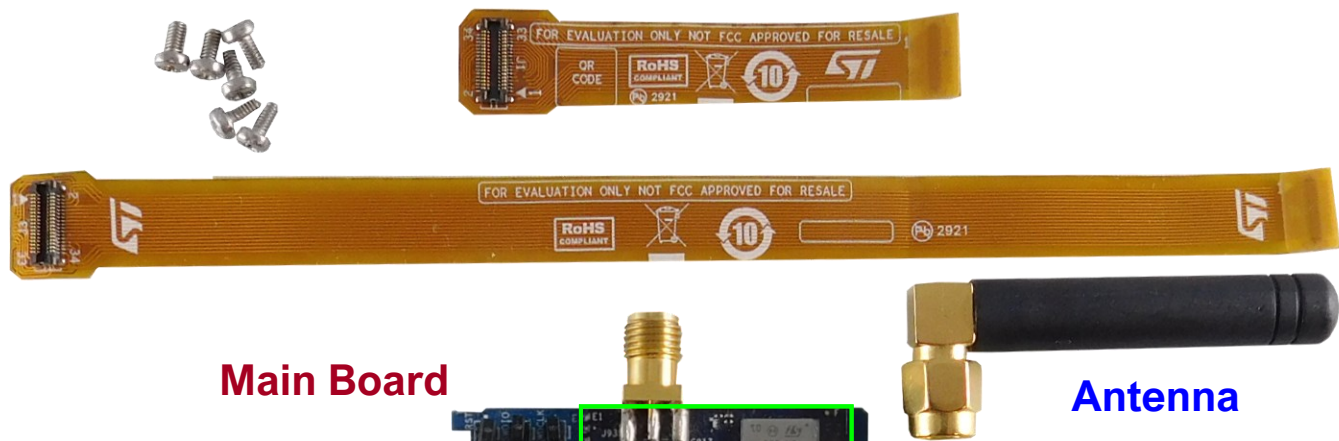
- ❑ Main board (Code: **AB0072.B.01**) including
 - ❖ Solderable PCB with **STM32WB** module, **STM32WL**, **STSAFE**, **ST1PS02** devices (Code: **AB0037.C.02**)
 - ❖ Three power management paths to supply the system
 - ❖ Two expansion connector (34 Pins)
 - ❖ 1 STSAFE (WL)
 - ❖ 2Gbit External Memory (NOR with QuadSPI)
 - ❖ Several protection devices
- ❑ Expansion #1 (Code: **AB0073.B.01**)
Motion – Temperature Sensors board
- ❑ Expansion #2 (Code: **AB0074.B.01**)
Environmental, Audio, Presence detection Sensors board



STDES-CBMLoRaBLE: Hardware details



STDES-CBMLoRaBLE: Kit details & assembly solutions



Main Board

Antenna

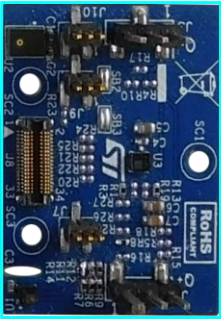
SB Module
STM32WB
+
STM32WL

EXP1



IIS3DWB
ISM330DHCX
IIS2ICLX
STTS22HH

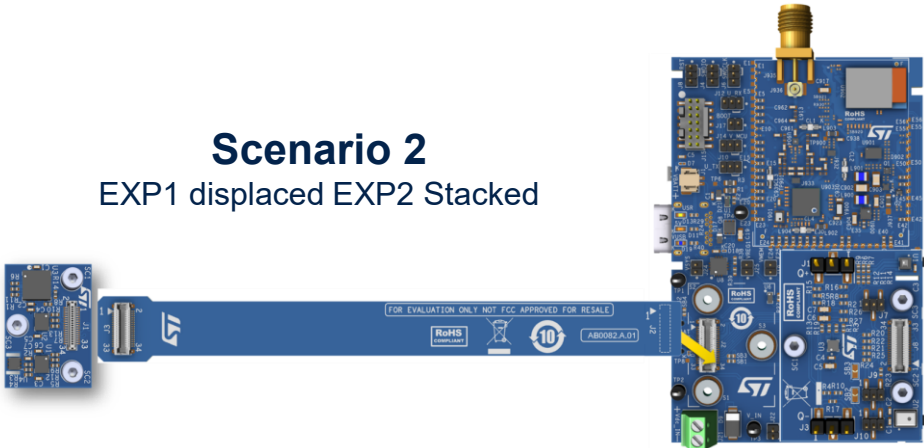
EXP2



ILPS22QSTR
IMP34DT05A



Scenario 1
All boards stacked



Scenario 2
EXP1 displaced EXP2 Stacked

STDES-CBMLoRaBLE: System Setup



STDES-CBMLoRaBLE: Connection Scenarios

In full run mode, both connectivities – short and long range – are available and user may monitor the system by the mobile App or by a remote dashboard. Environmental data and data from Condition Based Monitoring (CBM) processing can be monitored by:

❑ DSH-PREDMNT AWS Dashboard – Remote monitoring



Monitoring, automatic messages for recovery, status detection and data storage available on cloud

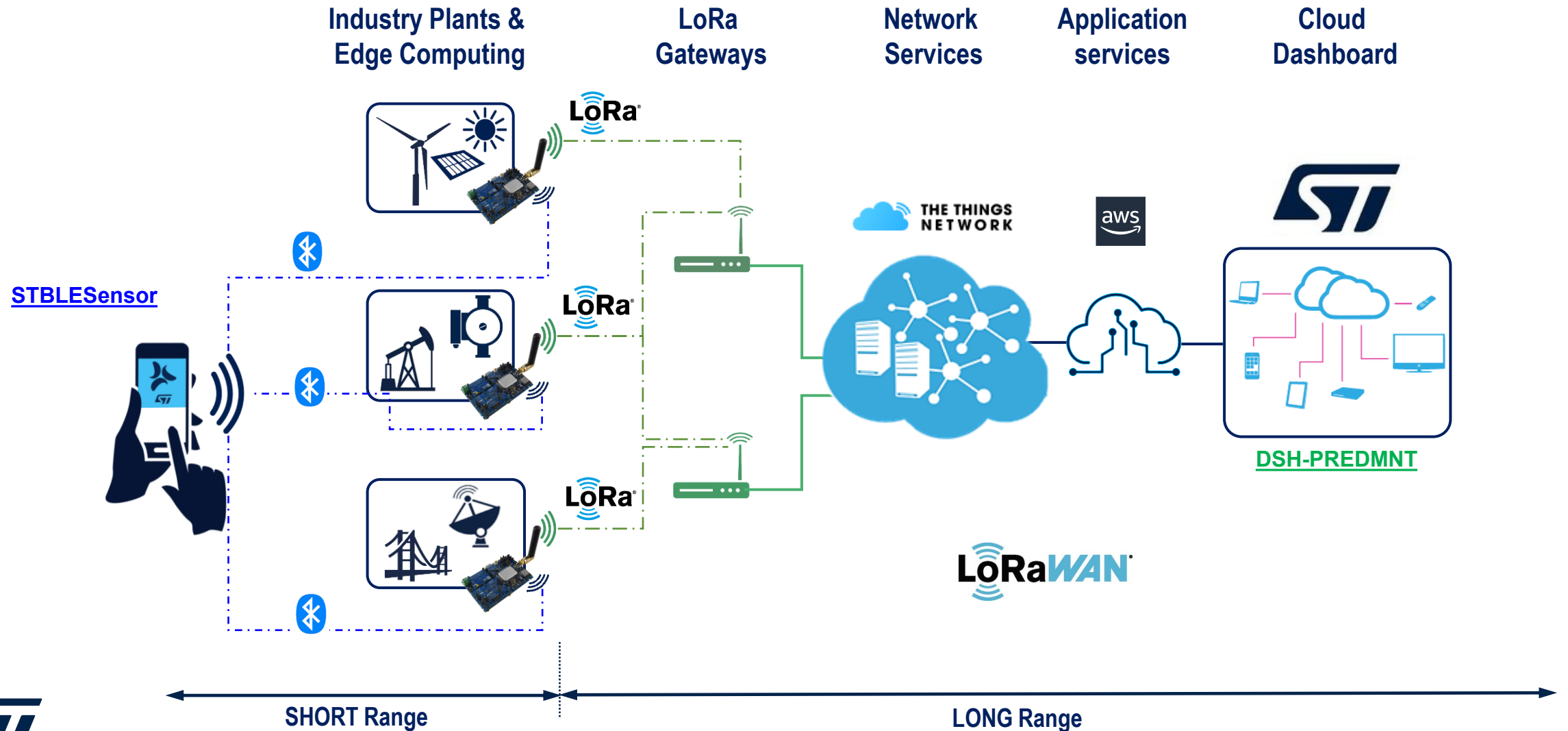


❑ BLE Sensor App – Nearby monitoring

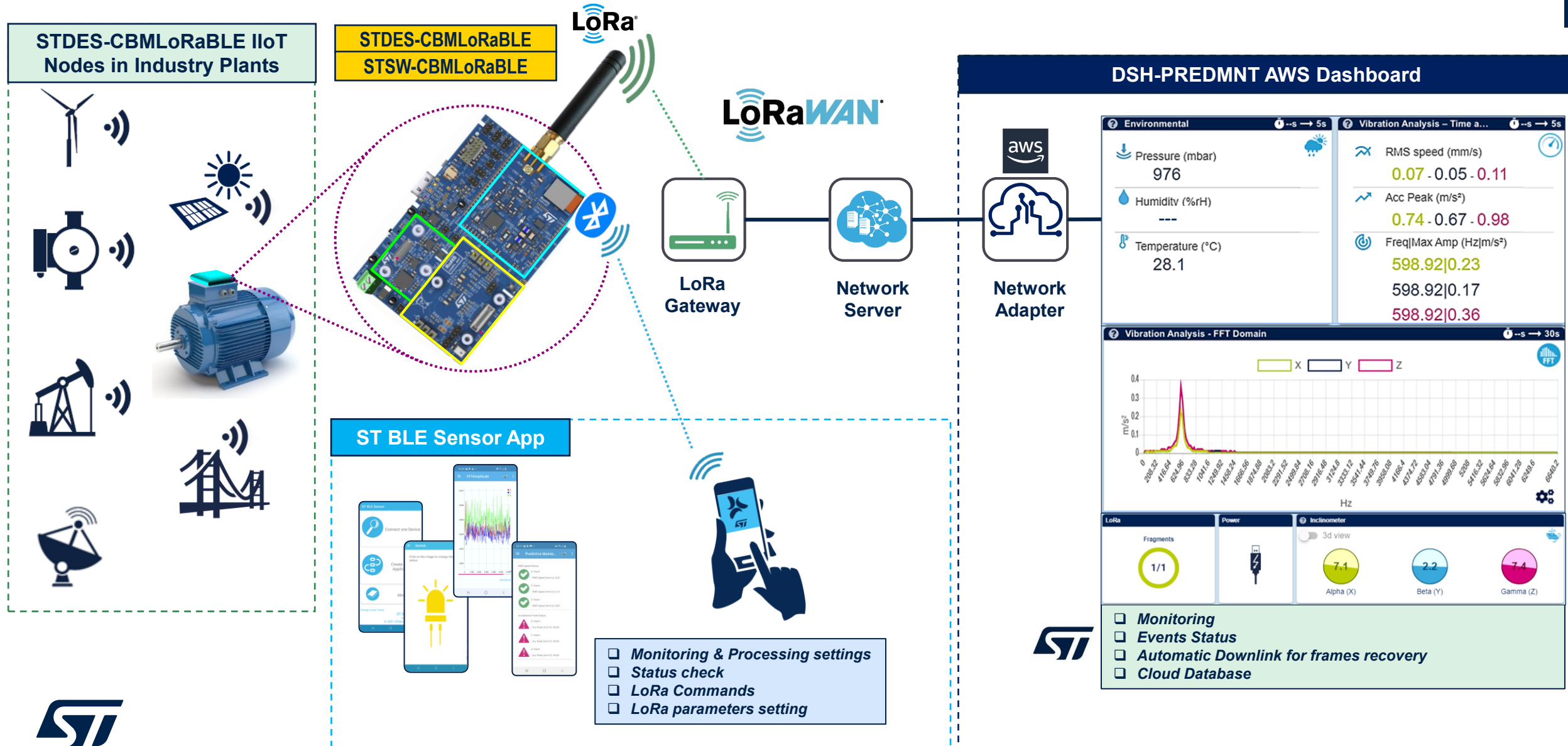


Data are monitored according to the active page on the App. When connected, user is allowed to update some sensors parameters and LoRa transmission settings

Industrial connectivity for STDES-CBMLoRaBLE

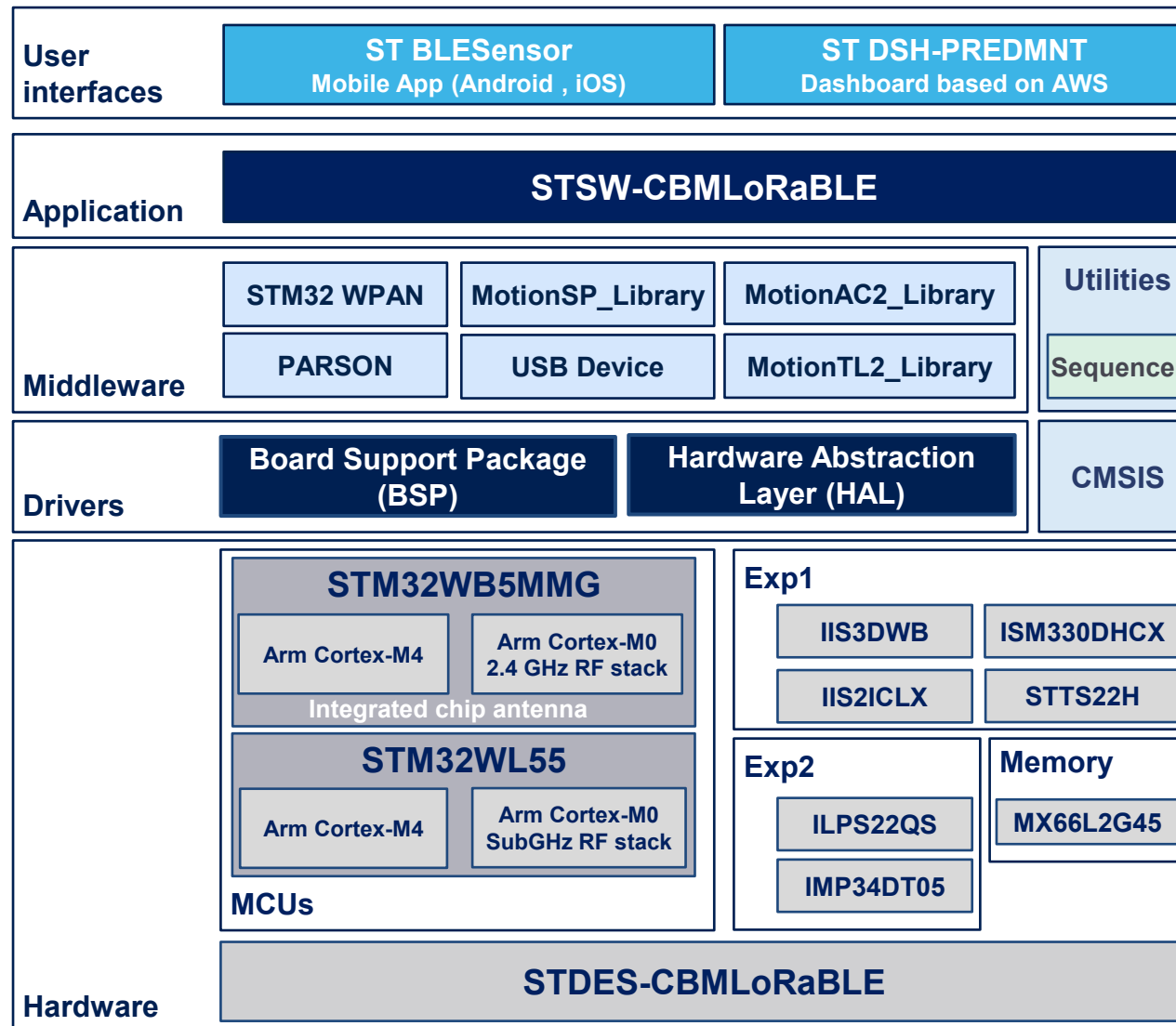


STDES-CBMLoRaBLE: Multi connectivity application overview

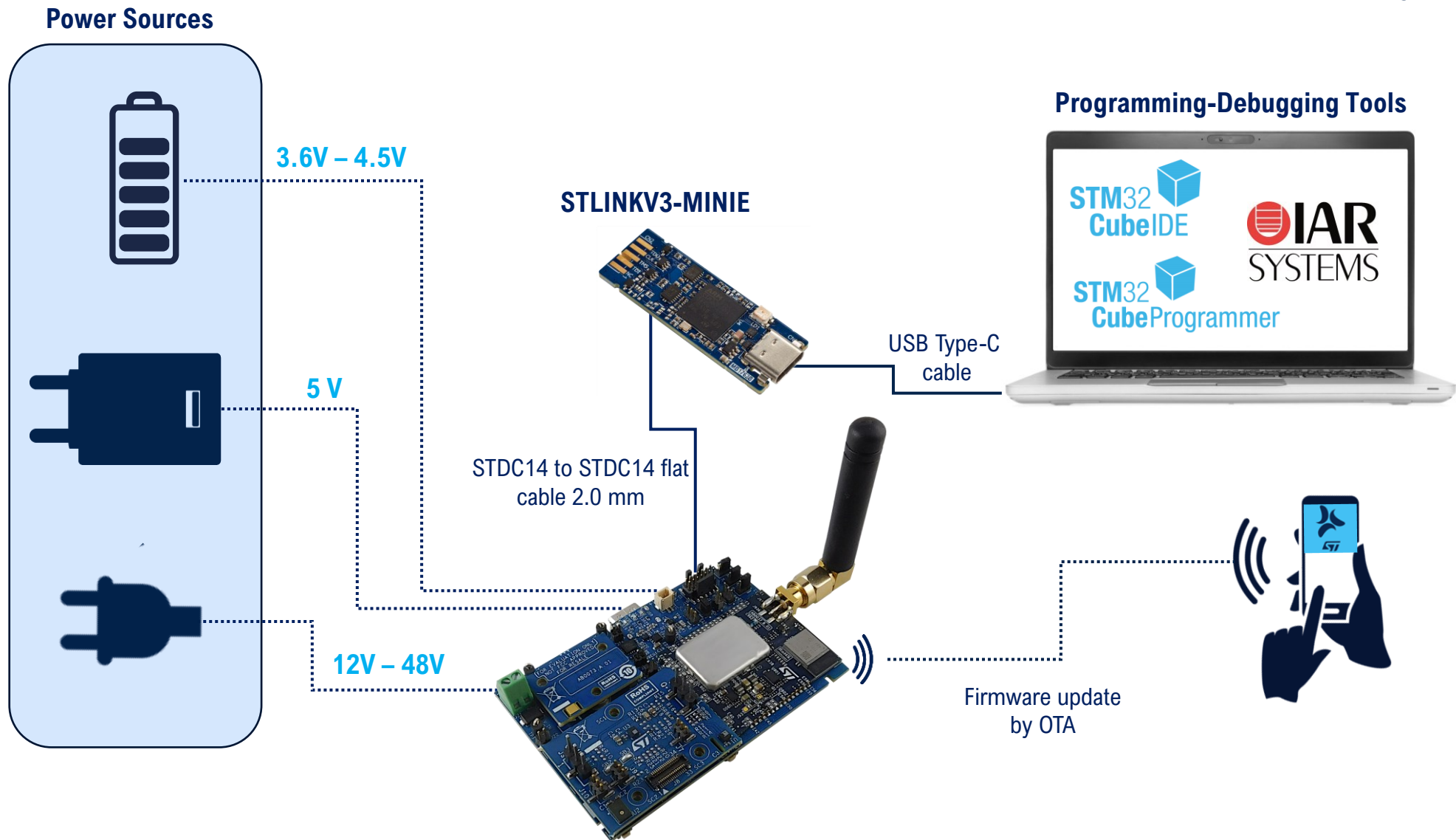


STSW-CBMLoRaBLE: Firmware Overview

Firmware architecture based on Sequencer



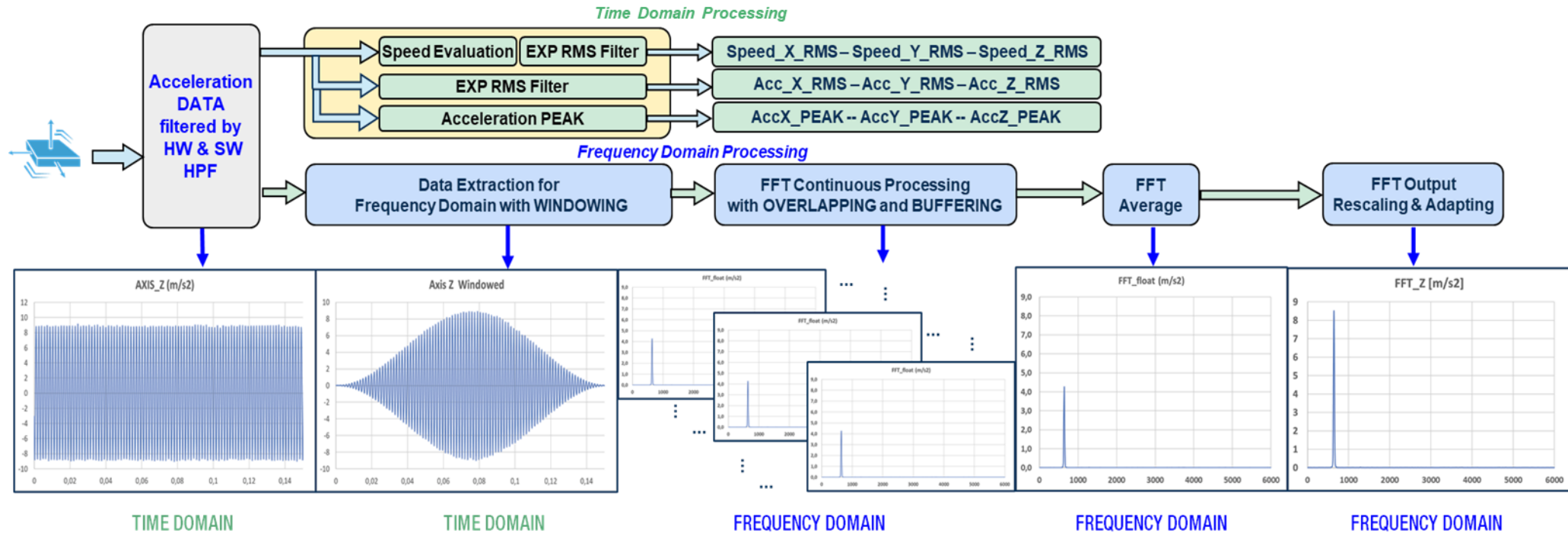
Power options, programming connections and Firmware update by OTA



STSW-CBMLoRaBLE: Embedded Processing

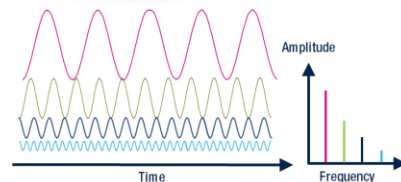
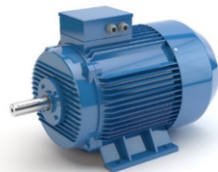


Time and Frequency domain analysis with MotionSP



Time Domain Analysis:

- Speed Estimation
- Exponential Filtering for RMS moving average (Speed or Acceleration)
- Max acceleration peaks



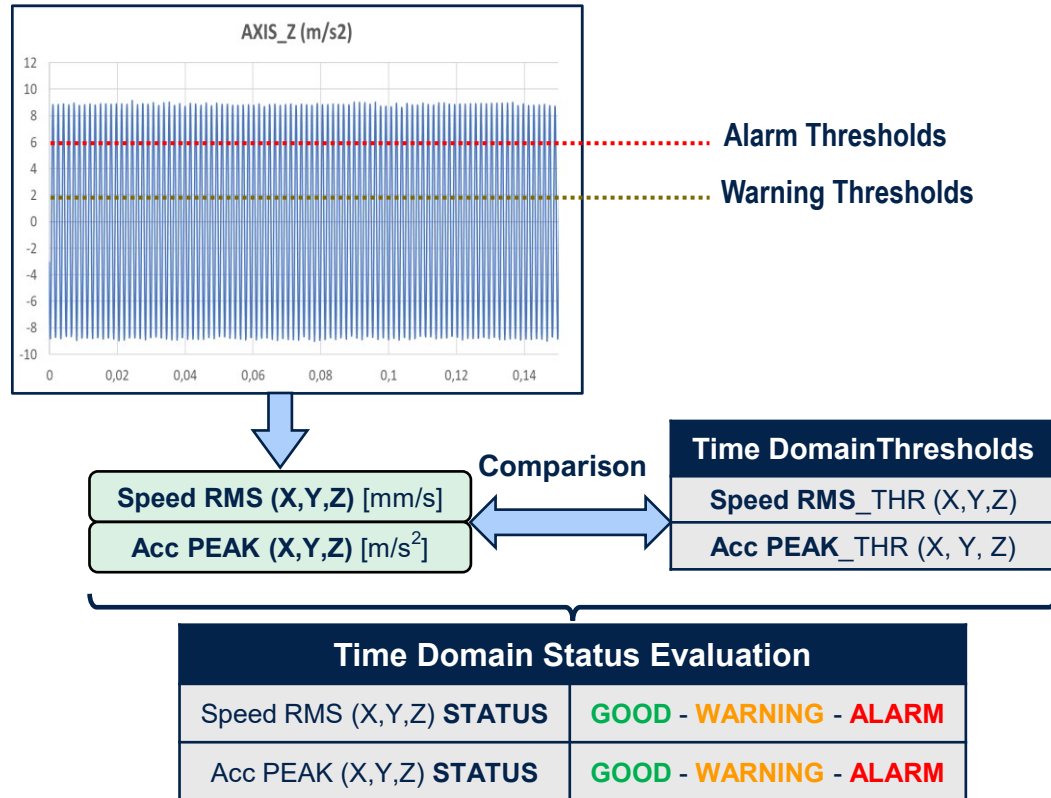
Frequency Domain Analysis:

- Programmable FFT size: 256, 512 points
- Programmable windowing Methods: Rectangular, Hanning, Hamming, Flat Top
- Programmable FFT overlapping percentage
- Programmable acquisition total time for analysis
- FFT averaging during acquisition time

Predictive Maintenance Status Messages

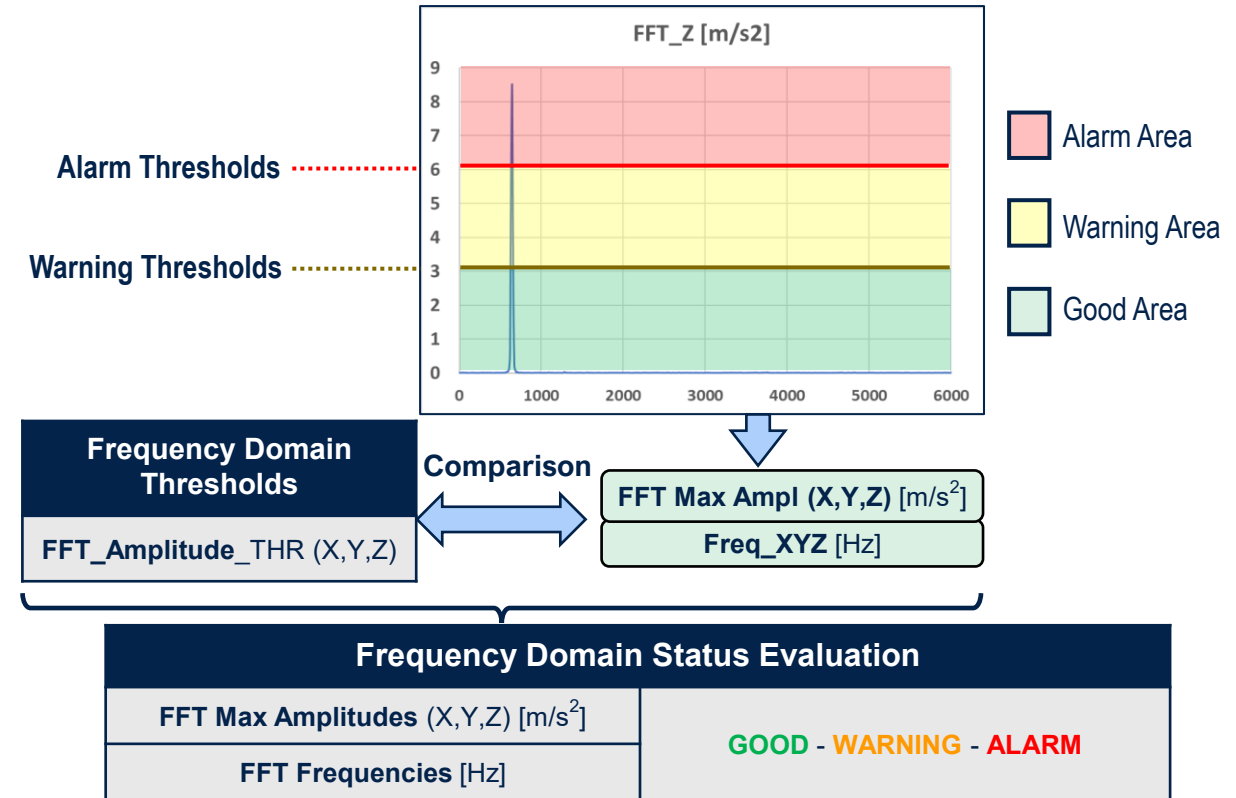
❑ Time Domain Analysis:

- Speed RMS evaluation and comparison with thresholds
- Acceleration Max Peak evaluation and comparison with thresholds



❑ Frequency Domain Analysis:

- FFT max amplitude evaluation and comparison with thresholds



Inclination measurement

Inclination monitoring

- ❑ An interesting inclination measurement can be performed using a specific low noise MEMS accelerometer with the proper algorithms^(*) to evaluate the angles starting just from the acceleration data.
- ❑ The results can be listed as follow:

- ❖ **Alpha** → α

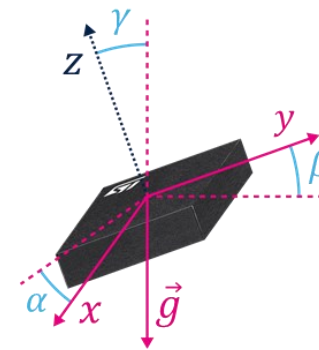
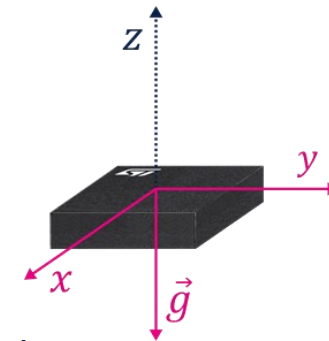
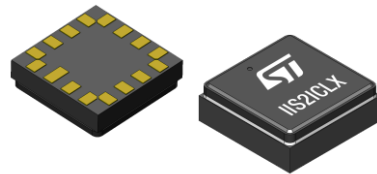
Angle between the MEMS x-axis (**Xs**) and the horizontal plane (**Xg**)
Its value can change in the range: **-90 ÷ 90** degrees.

- ❖ **Beta** → β

Angle between the MEMS y-axis (**Ys**) and the horizontal plane (**Yg**)
Its value can change in the range: **-90 ÷ 90** degrees.

- ❖ **Gamma** → γ

Angle between the MEMS XY plane (**Xs - Ys**) and the horizontal plane (**Xg - Yg**).
Its value can change in the range: **0 ÷ 90** degrees, for a 2-axis accelerometer.



Alpha → α



Alpha (X)

Beta → β



Beta (Y)

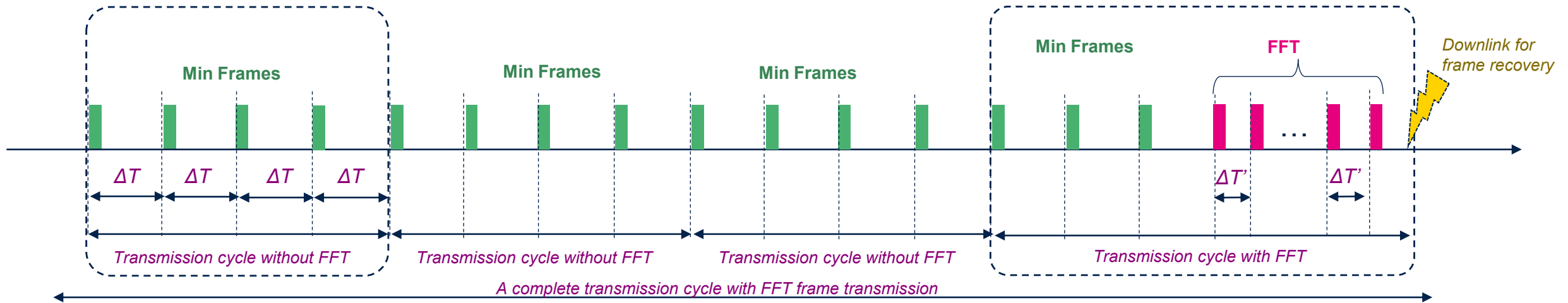
Gamma → γ



Gamma (Z)

STSW-CBMLoRaBLE: LoRa Dynamic Frames

Frames transmission scheme



Minimum Frame

- ☐ Environmental (Temp, Press)
- ☐ Inertial TDM (Acc peak&Status, speed RMS&Status)
- ☐ Inertial FDM results (Max Ampl, Bin freq)
- ☐ Inclinometer data (α, β, γ)
- ☐ Battery (Voltage)
- ☐ Status (Total status TD | FD)

~ 50 Bytes

> 500 - 1k Bytes

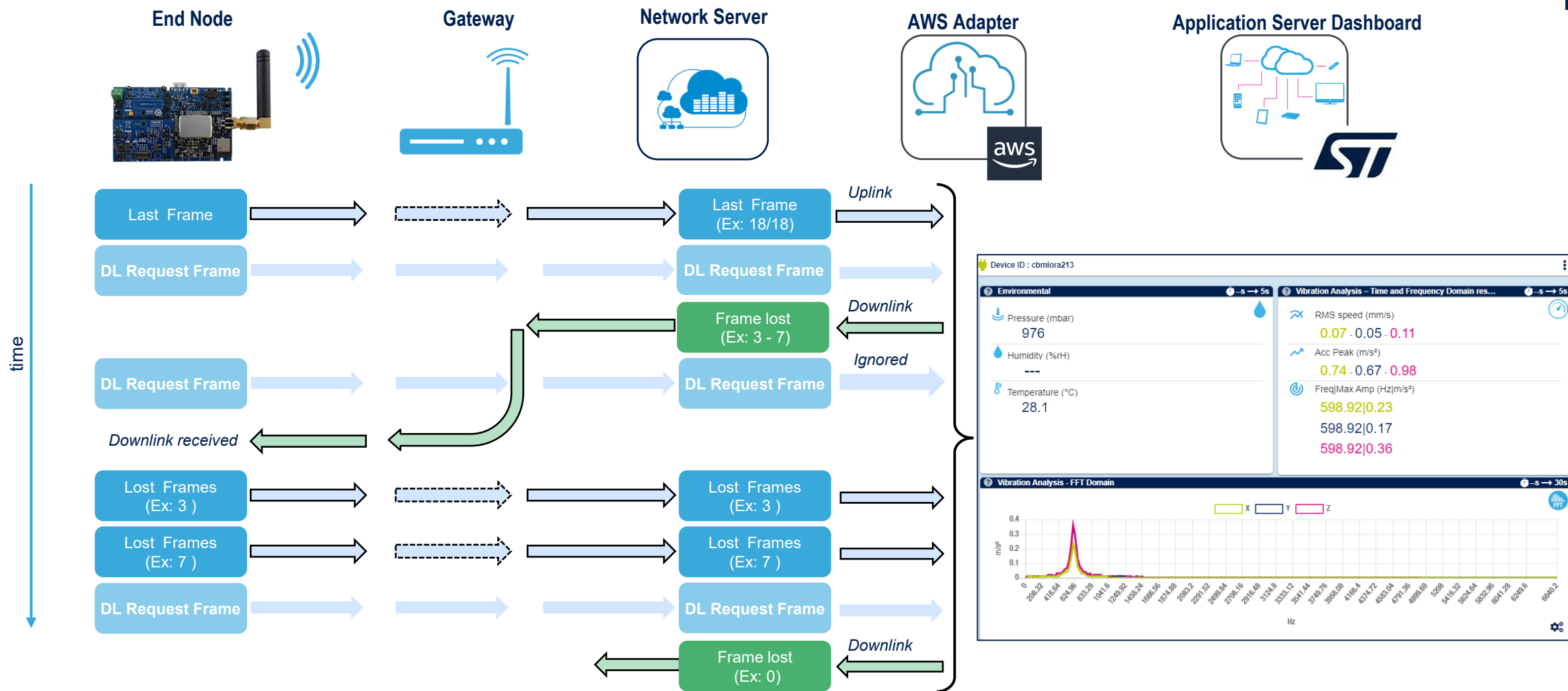
Maximum frame (sent by fragmentation)

- ☐ Environmental (Temp, Press)
- ☐ Inertial TDM (Acc peak&Status, speed RMS&Status)
- ☐ Inertial FDM (FFT)
- ☐ Inclinometer data (α, β, γ)
- ☐ Battery (Voltage)
- ☐ Status (Total status TD | FD)

Additional FFT frames transmission started with following conditions:

- ☐ Cyclically every more elapsed time interval
- ☐ Forced by pressing User button (SW1)
- ☐ On demand using the related custom commands available on BLE App

STDES-CBMLoRaBLE LoRaWAN architecture



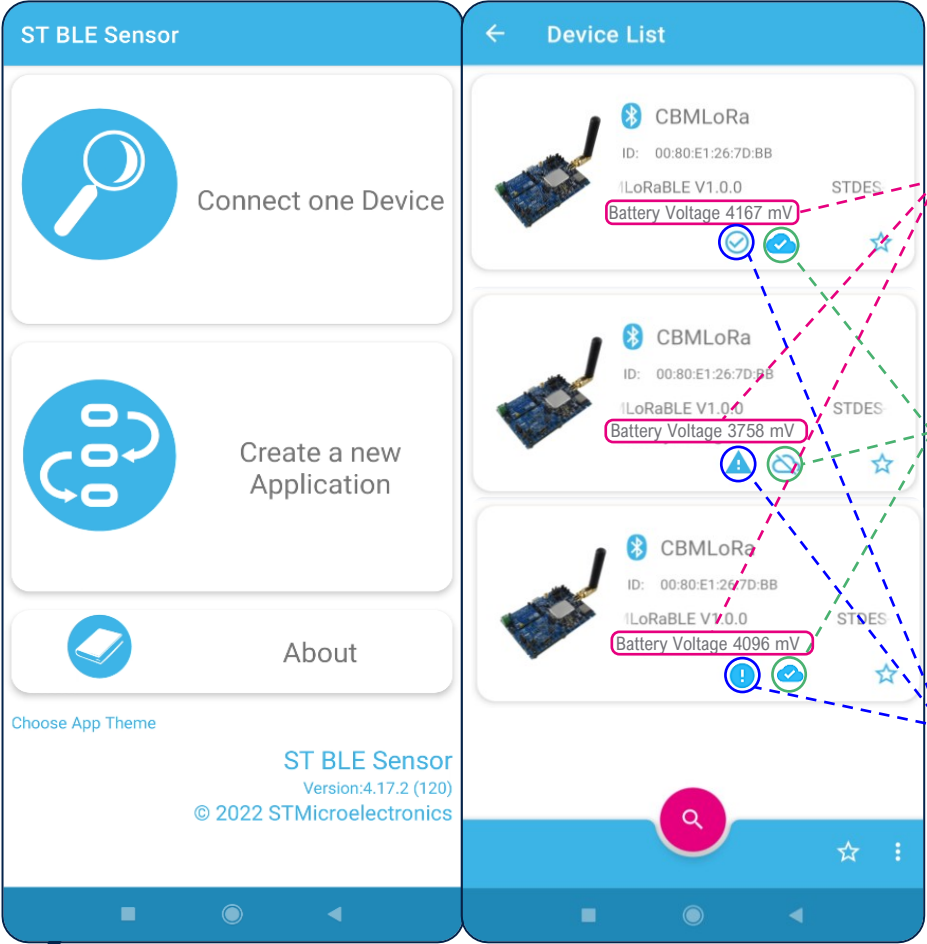
FRAGMENTATION is automatically used when the DATA frame length exceeds the maximum payload size allowed. An **Uplink/Downlink mechanism** is implemented in order to recover possible lost packages of a fragmented frame.

Using the BLE Mobile App



STBLESensor mobile app for Android and iOS

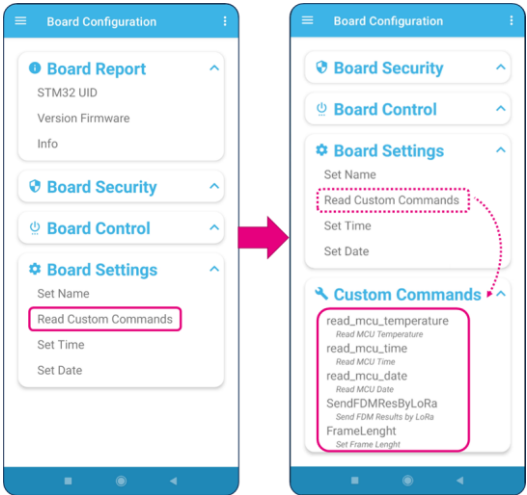
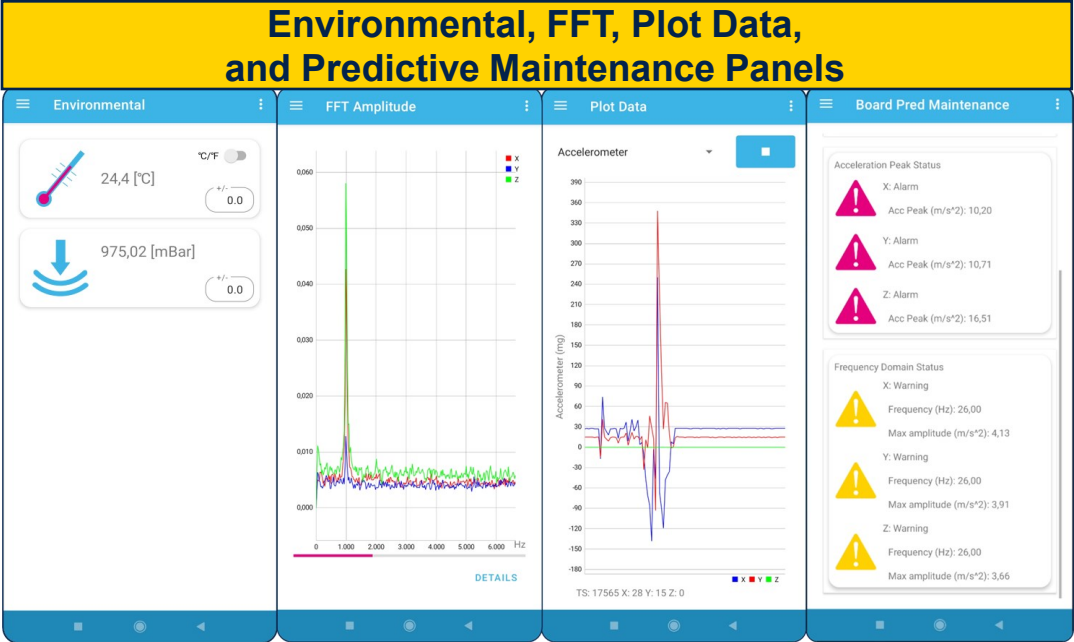
BLE Sensor App information in advertising



Battery Voltage

LoRa connection status
NetServer connected or Not

PDM Asset Status
Good, Warning, Alarm

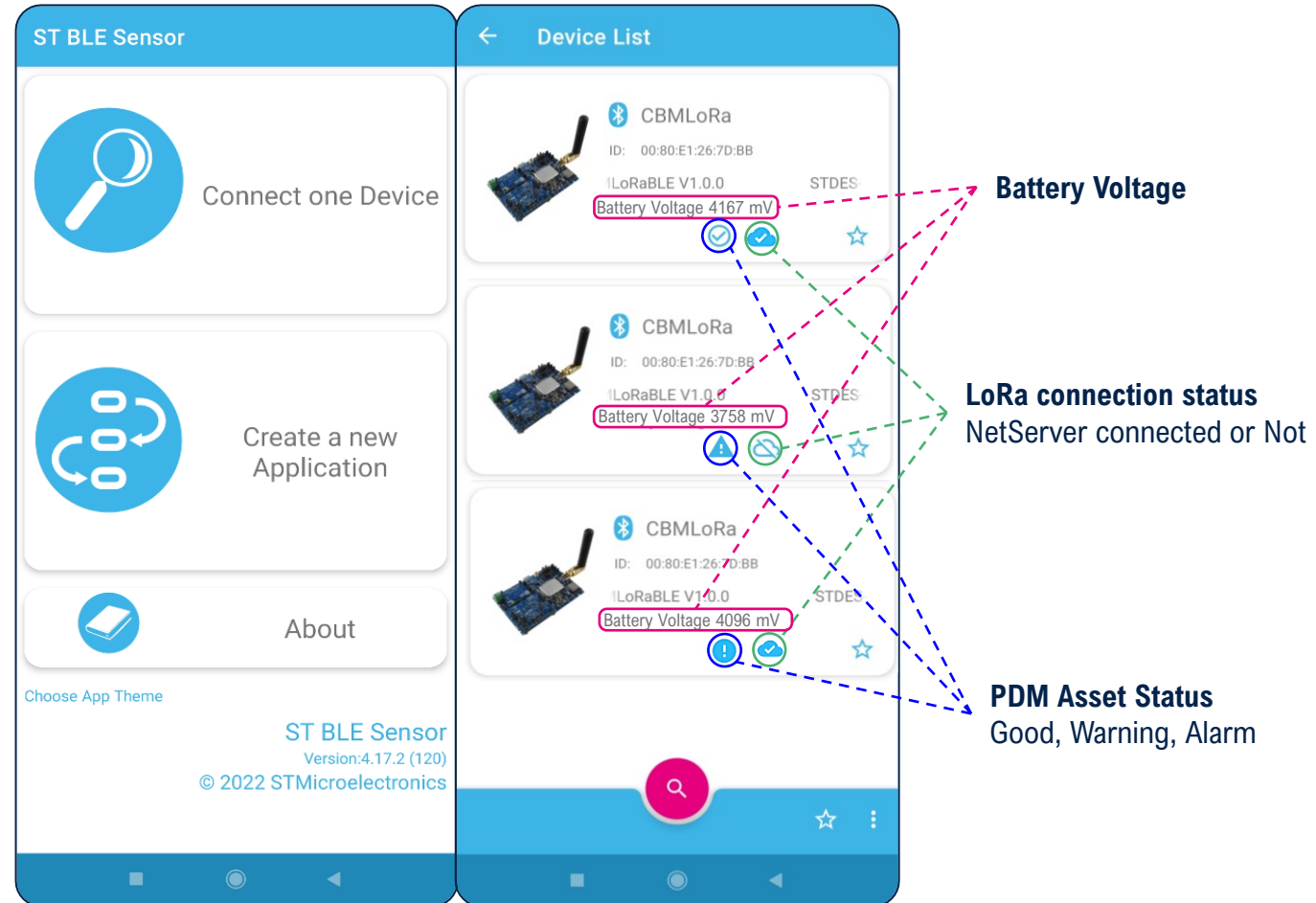


Use Custom Commands to control LoRa transmission



STBLESensor mobile app for Android and iOS

Open the BLE Sensor App and check the information in advertising





STBLESensor mobile app for Android and iOS

View Environmental FFT, Plot Data, and Predictive Maintenance Panels



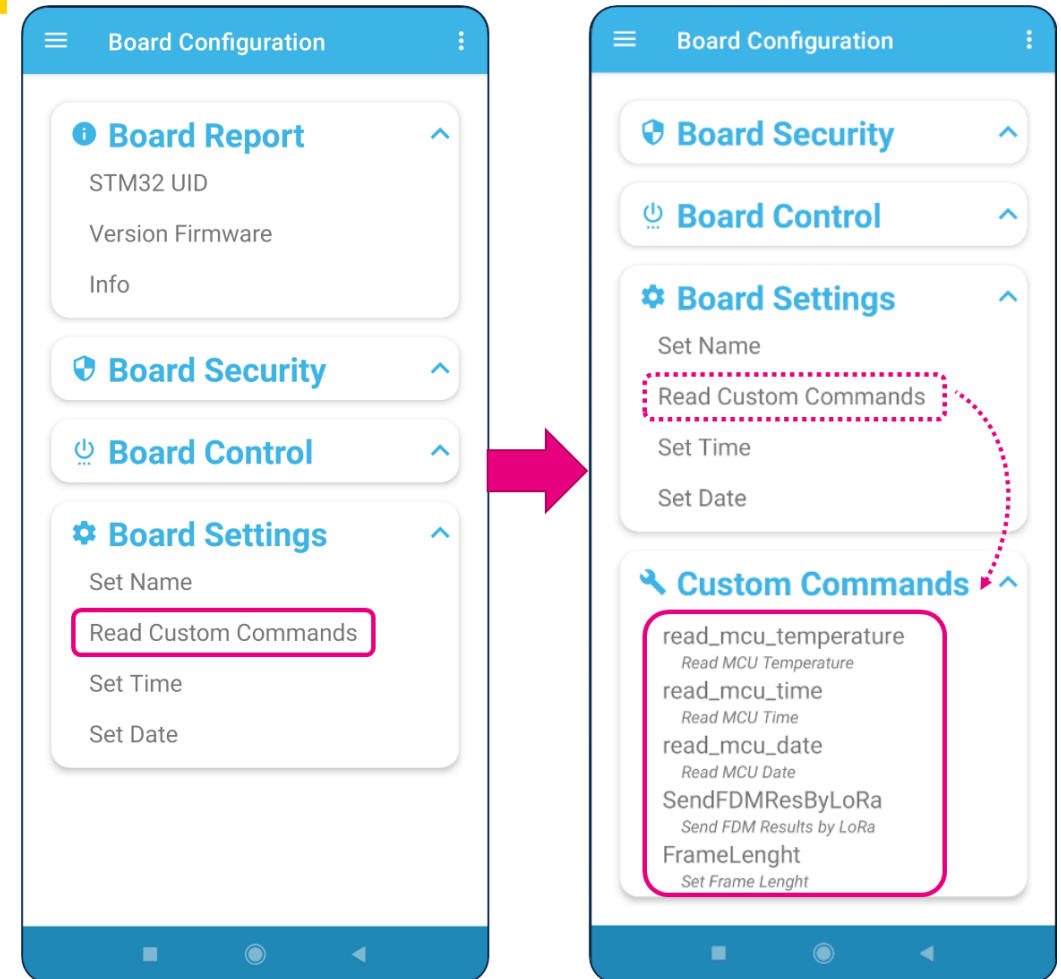


STBLESensor mobile app for Android and iOS

Use Custom Commands to control LoRa transmission

Open the **Board Configuration** demo window and scrolling down access to the **Board Settings** panel.

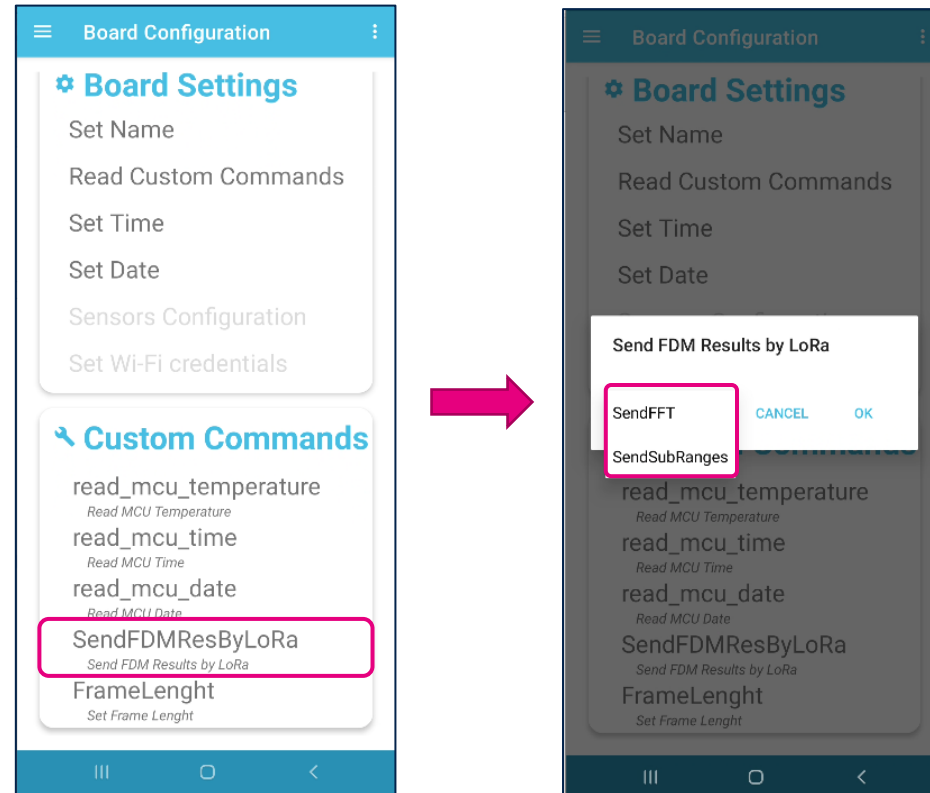
Read Custom Commands section is used for fast reading/modification of parameters and to force sending of FFT frame or SUB frame by LoRa





Read Custom Commands (1/2)

By pushing **SendFDMResByLoRa**, Frequency Domain Measurements (FFT) may be sent by LoRa



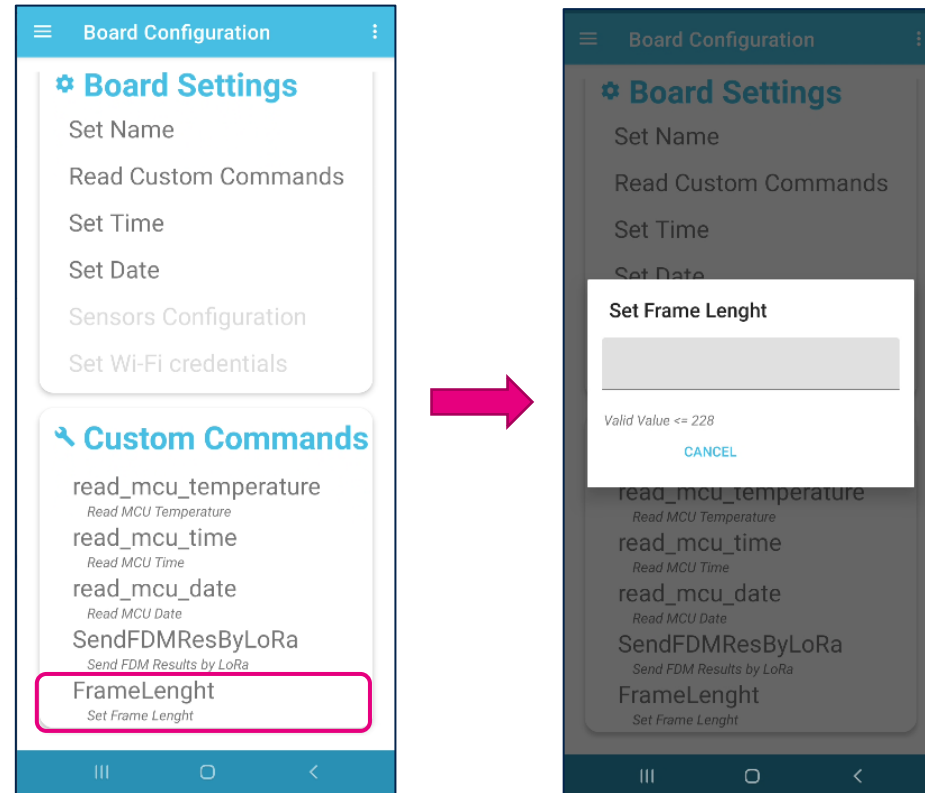


Read Custom Commands (2/2)

By pushing **FrameLenght**, the frame size may be updated.

The user must be aware of the LoRa transmission conditions and decrease it by 2 (*)

i.e. maximum allowed (EU868, DR = 4:7) is $228 = 230 - 2$



(*) RP002-1.0.3 LoRaWAN® Regional Parameters, 2021 Lora Alliance

Using the Predictive Maintenance Dashboard



Create a profile on TTN network server

The screenshot shows the TTN website with the following elements:

- Navigation Bar:** Includes links for Learn, Hardware, Forum, Community, Conference, and Enterprise. A user profile icon is on the right.
- Header:** Features the TTN logo and a navigation bar.
- Main Content:**
 - Step 1:** A yellow box with a circled '1' contains the text: "Connect to <https://www.thethingsnetwork.org> And create a user profile".
 - Text:** "We are a global collaborative Internet of Things ecosystem that creates networks, devices and solutions using LoRaWAN®."
 - Buttons:** "Start building" (highlighted with a yellow arrow) and "Learn more".
 - Step 2:** A yellow box with a circled '2' contains the text: "Push Start Building to choose the network server".
- Map:** A large globe showing the distribution of TTN nodes, with a high concentration in Europe.
- Footer:** A row of statistics: 48.7M Messages today, 151 Countries, 1.1K Certified developers, 169.8K Members, 20.1K Gateways, 1.6M YouTube views, 14.8K YouTube subscribers, 693 GitHub stars, 13.1K GitHub commits, and 18.9 Twitter foll.

Select Europe cluster in TTN network

The screenshot shows the 'The Things Network Cluster Picker' interface in a web browser. The browser's address bar displays 'console.cloud.thethings.network'. The interface is divided into two main sections: a left sidebar and a right map area.

Left Sidebar:

- THE THINGS NETWORK** logo and title.
- The Things Network Cluster Picker** subtitle.
- Select a cluster to start adding devices and gateways.** instruction.
- Europe 1** cluster, labeled 'eu1 - Dublin, Ireland'. This cluster is highlighted with a pink border, and a yellow mouse cursor is pointing at it.
- North America 1** cluster, labeled 'nam1 - California, United States'.
- Australia 1** cluster, labeled 'au1 - Sydney, Australia'.
- A **More information** button at the bottom of the sidebar.

Right Map Area:

- A world map showing the locations of the clusters.
- A blue dot is placed on the map over Europe, corresponding to the 'Europe 1' cluster.
- A tooltip box appears over the dot, containing the text **Europe 1** and 'eu1', with a **Choose** button.

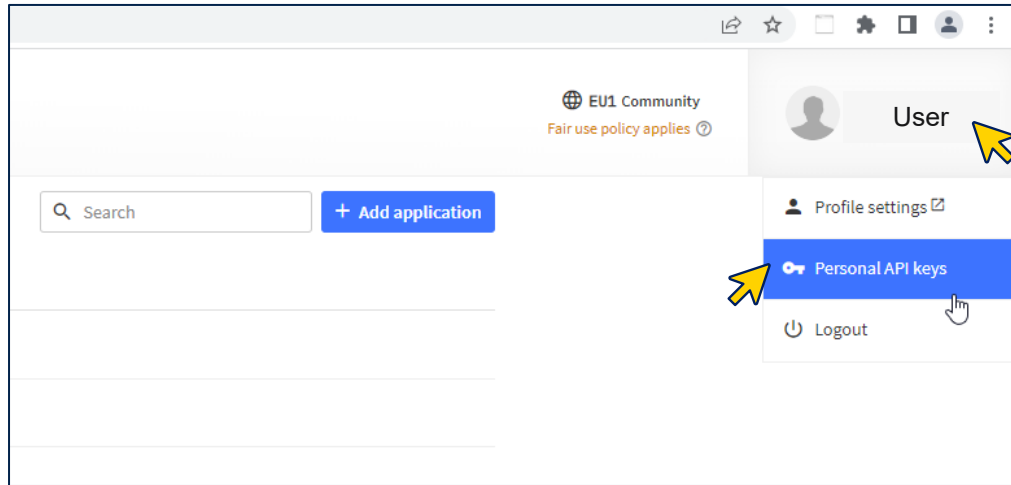
Bottom Bar:

- A yellow bar with the text *Complete registration saving the*.

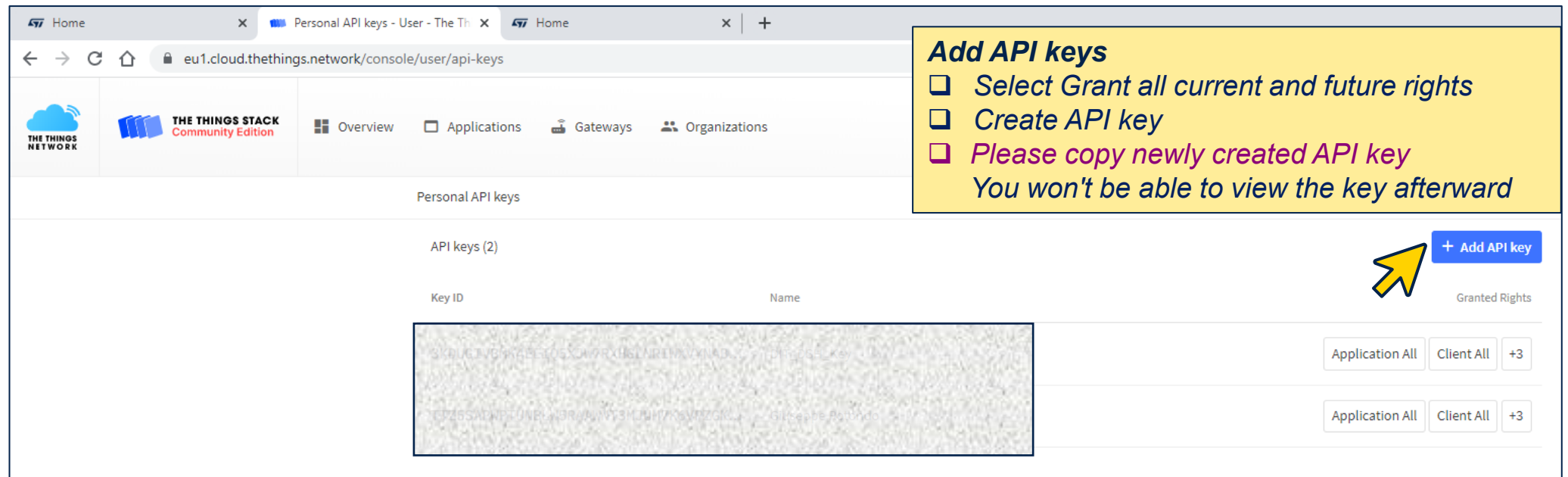
Footer:

- ST logo and 'life.augmented' text.
- A URL bar at the bottom left showing 'https://eu1.cloud.thethings.network/console/'.

Generate an API User key



Open the **Personal API keys**
To generate a new key to use in
the AWS PREDMNT DSH



Create a user profile on ST DSH-PREDMNT

Home

Personal API keys - User - The Th

dsh-predmnt.st.com

HOME CONFIGURATION DASHBOARD ASSETS CONDITION MONITORING SENSOR MAP DATA LAKE EVENTS

PREDICTIVE MAINTENANCE PLATFORM
Dashboard and Device Management

1. Configure a device
Open the configuration panel and add a new device and its identity card, downloads the certificates to enroll it. Set thresholds for alarm and warning notifications.

2. Add your devices for live monitor
Create your dashboard and see live data real-time from the cloud, look at the trends and gain insights.

3. Monitor your assets and control them
See how your thresholds configured works looking at the gauges; keep your attention on warning and alerts events to predict your maintenance.

4. Look at overall status
Find the list of your devices in the map, their status and get control of all events.

1 CREATED DEVICES

0 CREATED EDGES

Account Expiration
2022-10-20

User
Logout
Settings

EN

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PREDMAINT 1.40.0

Add your LoRa application profile in Dashboard settings

The screenshot shows the dashboard of `dsh-predmnt.st.com` with a navigation bar containing `HOME`, `CONFIGURATION`, `DASHBOARD`, `ASSETS CONDITION MONITORING`, `SENSOR MAP`, `DATA LAKE`, and `EVENTS`. A user profile icon is in the top right.

A yellow callout box in the top right corner contains the text: *Add a new profile using the TTNv3 API key* and a circled number **1**.

The main content area features a **LoRa Profile** table with columns `Name ↑` and `network server`. It lists `cbmloragro` with `TTNV3` as the network server.

An **Add LoRa Profile** modal is open, showing the following fields and instructions:

- PROFILE**
 - Profile name**: `stdeslorable` (Instruction **2**: *Insert Profile name*)
 - Network server**: `TTNV3` (Instruction **3**: *Confirm the TTN network server*)
- NETWORK SERVER INTEGRATION**
 - Region**: `Europe` (Instruction **4**: *Confirm the Europe region*)
 - Api key (provide the personal api key)**: `NNSXS.4Y4QLN7L3FPF6XVDT332IBBUF2XDDIHVVAATJRI.FOB552ZUPWPL67B5U4I`


At the bottom of the modal are **CANCEL** and **SAVE** buttons. A yellow callout box at the bottom right says: *Insert the TTN API key saved before, and press SAVE*. A circled number **5** is next to the **SAVE** button, with a yellow arrow pointing to it.

Add your LoRa device in the dashboard

The screenshot displays the Predictive Maintenance Platform dashboard. The browser address bar shows the URL `d3b2vs0vfx045.cloudfront.net`. The navigation menu includes: HOME, CONFIGURATION, DASHBOARD, ASSETS CONDITION MONITORING, SENSOR MAP, DATA LAKE, and EVENTS. A user profile dropdown for 'User' is visible with options for Logout and Settings.


PREDICTIVE MAINTENANCE PLATFORM

Dashboard and Device Management



1. Configure a device


Open the configuration panel and add a new device and its identity card, download the certificates to enroll it. Set thresholds for alarm and warning notifications.



2. Add your devices for live monitor


Create your dashboard and see real-time from the cloud, look at the trends and insights.

Add the device to the Dashboard



3. Monitor your assets and control them

See how your thresholds configured works looking at the gauges; keep your attention on warning and alerts events to predict your maintenance.



4. Look at overall status

Find the list of your devices in the map, their status and get control of all events.

1

CREATED DEVICES

0

CREATED EDGES

Account Expiration
2022-10-20

EN Copyright © 2022 - STMicroelectronics PREDMAINT 1.40.0

Add your LoRa device in Dashboard

Provisioning keys available by terminal console

```
*****
STMicronics
STDES-CBMLoRaBLE V1.0.0
CMSIS Core(M) U5.3
HAL V1.10.0 RC0
Compiled Oct 7 2022 17:52:58 (openstm32)
*****
Powered by:
STM32WB5MMG - Bluetooth® Low Energy 5.0 and 802.15.4 module
Multiprotocol wireless 32-bit MCU Arm®-based Cortex®-M4/M0
*****
MCU Unique device ID is 0x112233445566778899AABBCC
MCU Flash Size is 1024 KB
*****

** Expansion #1 initialization... **
**** Expansion #1 initialized **

** Expansion #2 initialization... **
**** Expansion #2 initialized **

BD Name CBMLoRa
BD Address 00:80:E1:26:7D:BB } BLE Address
BLE Stack V1.13.0             } BLE Stack @ FUS release
BLE Stack Branch 0 Type 5
FUS V1.2.0

Successfully Start Fast Advertising
LoRa MODULE READY

*****
LoRa Device Keys for registration -----
DevEUI = 11:22:33:44:55:66:77:88
AppEUI = 01:01:01:01:01:01:01:01
AppKey = 11:22:33:44:55:66:77:88:99:AA:BB:CC:DD:EE:FF
*****
```

Find the new node in DASHBOARD tab

1

2

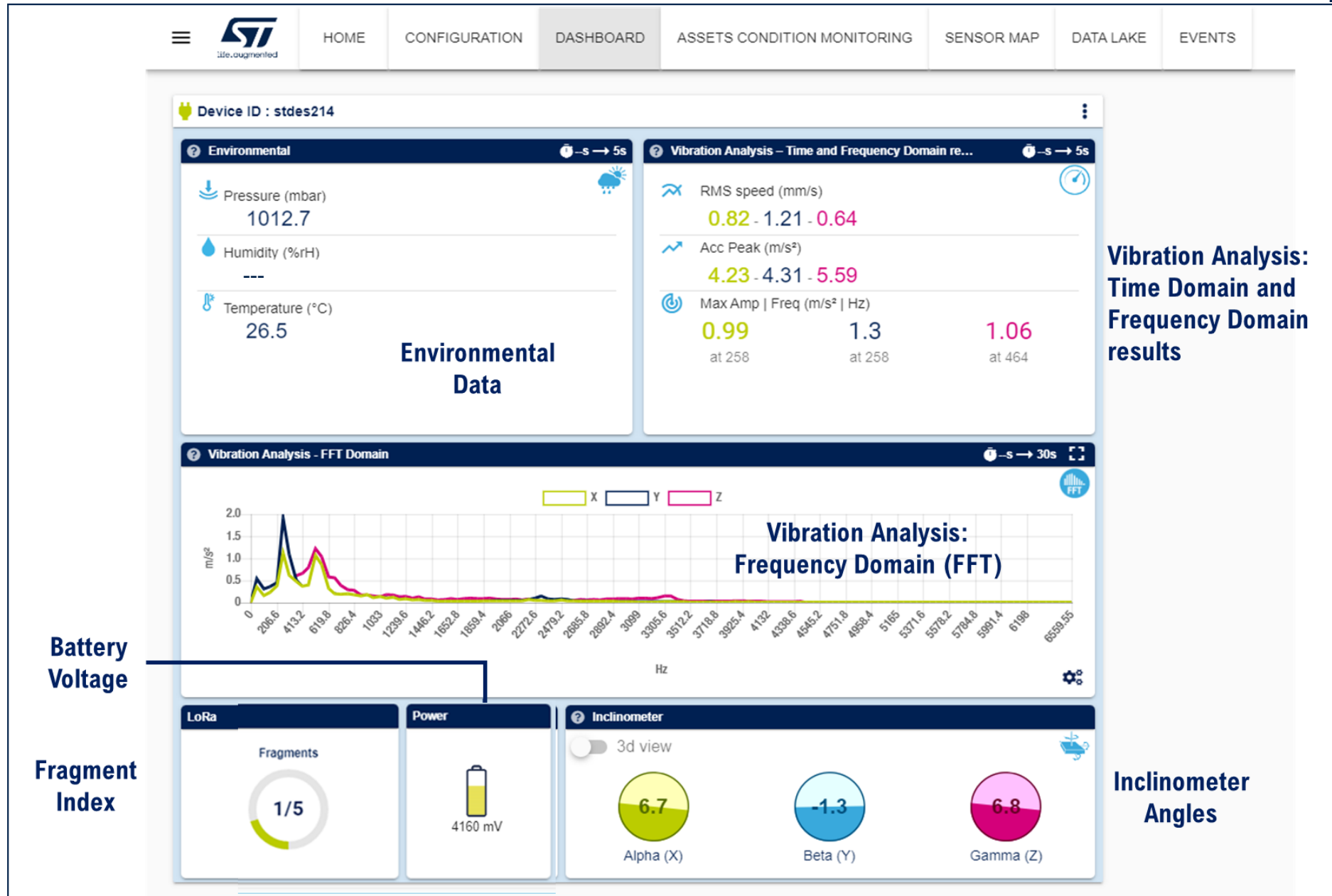
3

Press ADD to complete the registration of the node

ADD



DSH-PREDMNT main page



Vibration Analysis:
Time Domain and
Frequency Domain
results


Vibration Analysis:
Frequency Domain (FFT)

Battery
Voltage

Fragment
Index

Inclinometer
Angles

DSH-PREDMNT Events page

life.augmented

HOMECONFIGURATIONDASHBOARDASSETS CONDITION MONITORINGSENSOR MAPDATA LAKEEVENTS

Events

Device

Event type

From2022-09-25To2022-09-26

☐ info☐ warning☐ alarm☐ critical

[Last day](#)[Last week](#)[Last month](#)[Last 3 months](#)

TIMESTAMP	SEVERITY	DEVICE	INFORMATION
2022 Sep 26 18:57:54	ALARM	stdes100	- Acc - X Peak threshold exceeded
2022 Sep 26 18:57:54	ALARM	stdes100	- Acc - Y Peak threshold exceeded
2022 Sep 26 18:57:54	ALARM	stdes100	- Acc - Z Peak threshold exceeded
2022 Sep 26 18:53:04	ALARM	stdes100	- Acc - X Peak threshold exceeded

<12>

Open every events to understand the root cause

The screenshot displays the 'EVENTS' section of the ST life.augmented interface. The top navigation bar includes links to HOME, CONFIGURATION, DASHBOARD, ASSETS CONDITION MONITORING, SENSOR MAP, DATA LAKE, and EVENTS. The 'Events' section features a filter bar with 'Device' and 'Event type' dropdowns, a date range selector (From 2022-09-25 to 2022-09-26), and checkboxes for 'info', 'warning', 'alarm', and 'critical'. Below the filter bar is a table of events with columns for 'TIMESTAMP' and 'SEVERITY'. The table shows four events, all with a severity of 'ALARM'. A modal window titled 'EVENT DETAILS' is open, showing a line graph of 'Peak Acceleration' over time. The graph highlights a peak of 3.2 m/s² at 2022 Sep 26 - 18:57:54.848. Below the graph, the 'INFORMATION' section states 'Acc - Y Peak threshold exceeded' and 'Threshold ALARM'.

TIMESTAMP	SEVERITY
2022 Sep 26 18:57:54	ALARM
2022 Sep 26 18:57:54	ALARM
2022 Sep 26 18:57:54	ALARM
2022 Sep 26 18:53:04	ALARM

EVENT DETAILS

stdes100

Peak Acceleration 2022 Sep 26 - 18:57:54.848


3.2 m/s²

INFORMATION

Acc - Y Peak threshold exceeded

Threshold **ALARM**

DSH-PREDMNT DATA LAKE page



HOMECONFIGURATIONDASHBOARDASSETS CONDITION MONITORINGSENSOR MAPDATA LAKEEVENTS

Devices and Time Periods

Select, from your collection, the devices and the historical time period for the download.

Select devices

stdes100

Select time period

Last month

Telemetry Domains

Select, for each device, the domain of measures related to be included into the download.

stdes100

☐ Environmental

☐ TDM

☐ FDM

☐ Acoustic

☐ Inclinator

☐ Battery

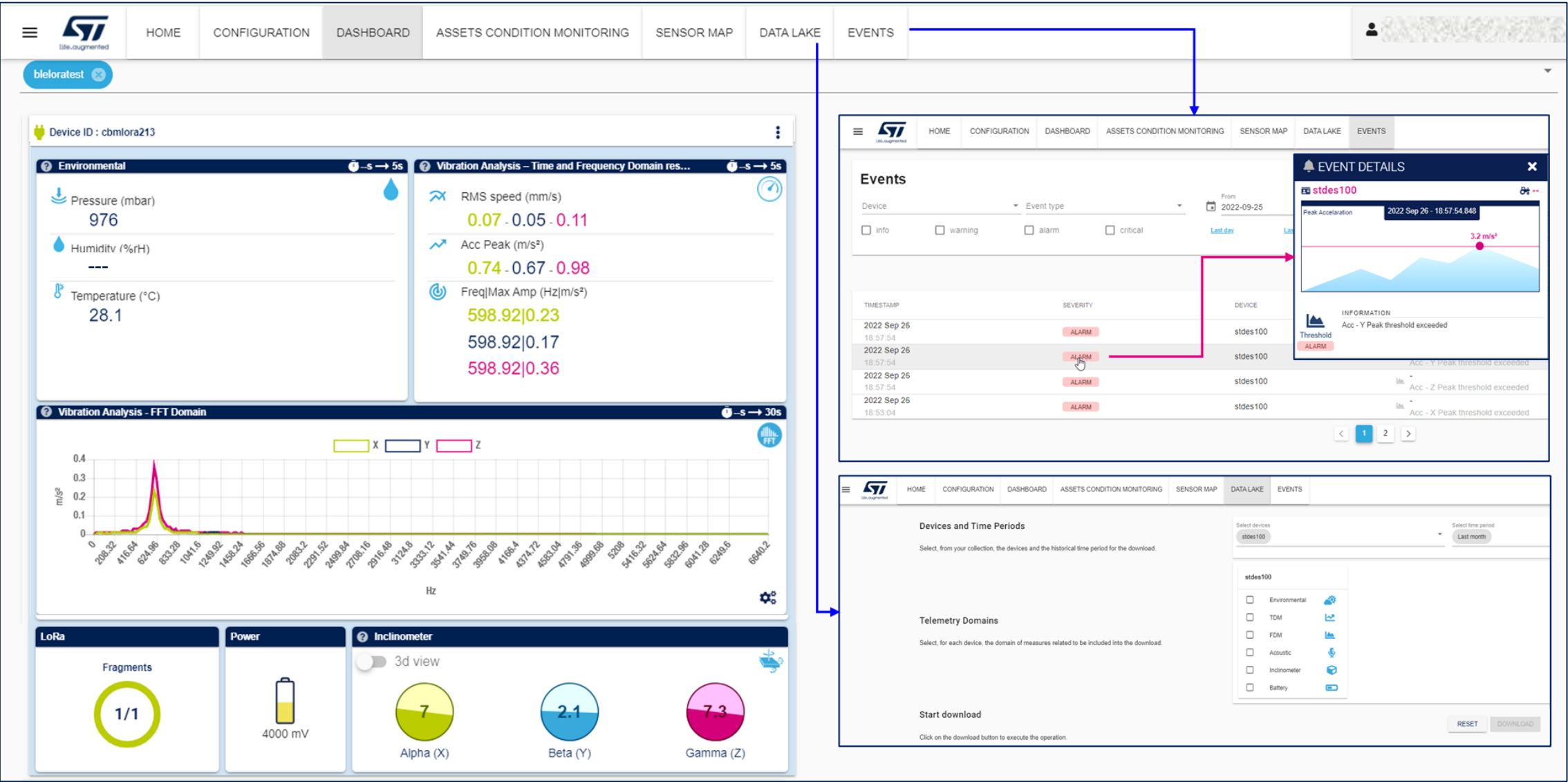
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RESET

DOWNLOAD

ST DSH PREDMNT: Live Data, Events and Data Lake



References

Documents available in related tab of each products webpage

❑ [STDES-CBMLoRaBLE](#)

- ❖ [DB4823](#): System platform with multiconnectivity and multisensors for IIoT application – HW Data brief Hardware
- ❖ [TN1429](#): STDES-CBMLoRaBLE test report – HW Testing report
- ❖ [White Paper](#): LoRa connectivity for Condition-Based and Predictive Maintenance in Smart Industry
- ❖ [Schematics](#), [BOM](#), [Gerber files](#)

❑ [STSW-CBMLoRaBLE](#)

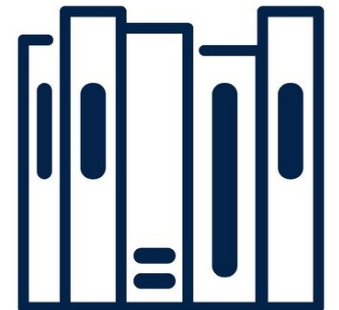
- ❖ [DB4874](#): Software package for the STDES-CBMLoRaBLE multiconnectivity and multisensor industrial solution – SW Data brief

❑ [SW TOOLS](#)

- ❖ [STBLESensor](#) : BLE sensor application for Android and iOS
- ❖ [DSH-PREDMNT](#): Cloud based web application for condition monitoring and predictive maintenance

❑ [IoT for Smart Industry:](#)

- ❖ [Smart Sensor Nodes](#)
- ❖ [Edge Processing](#)



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