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STDES – CBMLoRaBLE

System solution for IIoT applicatons with Multi Connectivity and Multi Sensors

V1.0

Jun 2023

Agenda

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STDES-CBMLoRaBLE: Application Overview

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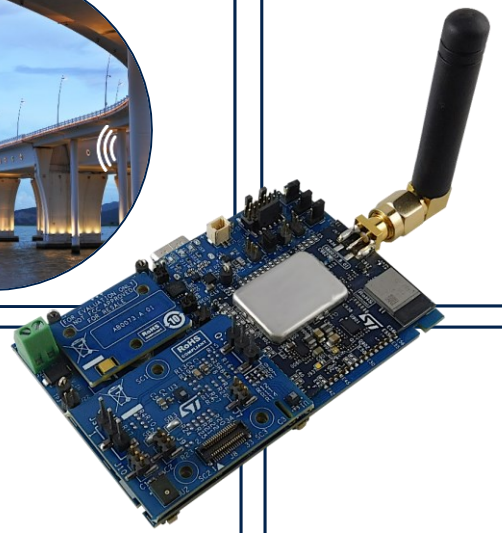
Industrial IoT Application Scenarios

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**)

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IIoT enabling different smart applications

Architecture Issue

- The **I**ndustrial **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.

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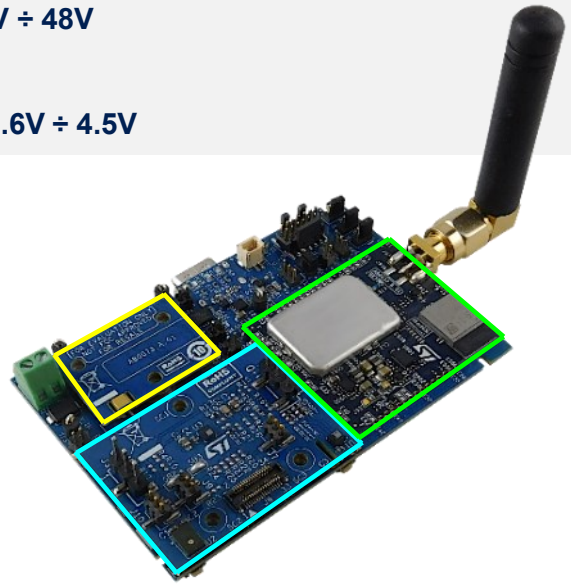
STDES-CBMLoRaBLE: Multi connectivity platform overview

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 Inclinometer, 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

STM32WB
216 CoreMark
64 MHz

STM32WL
162 CoreMark
48 MHz

STSAFE A110

Long & Short-range Connectivity

Power management & Protections

L7983
TCPP01
ESDALC6V1
ESDA25P35
USBLC6-2P6
ESDA7P120
ST1PS02

External Modules for MEMS Sensors

EXP1
- IIS3DWB (3D Vibrometer)
- IIS2ICLX (2D + MLC)
- ISM330DHCX (3D+3D+ MLC)
- STTS22H

EXP2
- IMP34DT05A
- ILPS22QS

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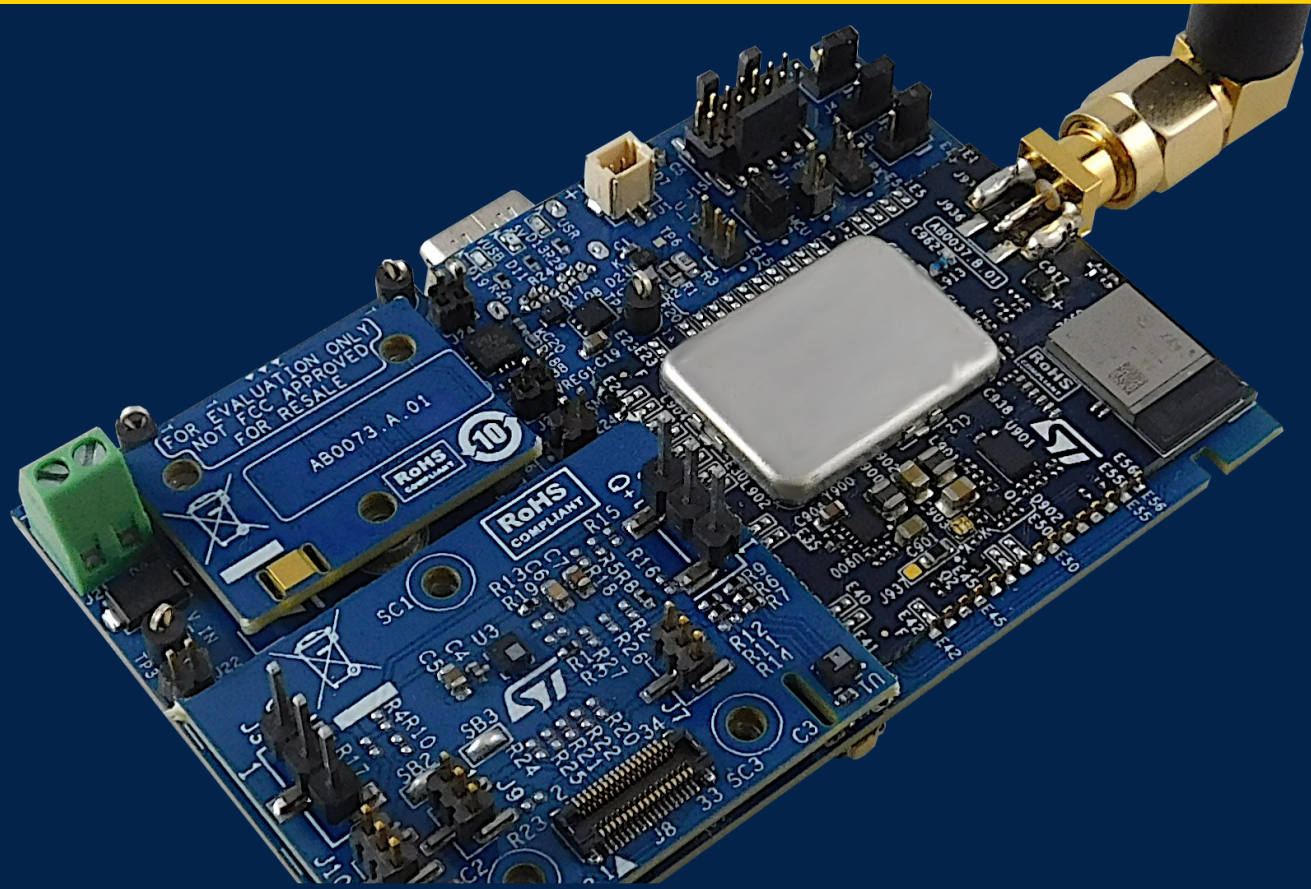
STDES-CBMLoRaBLE: Hardware Description



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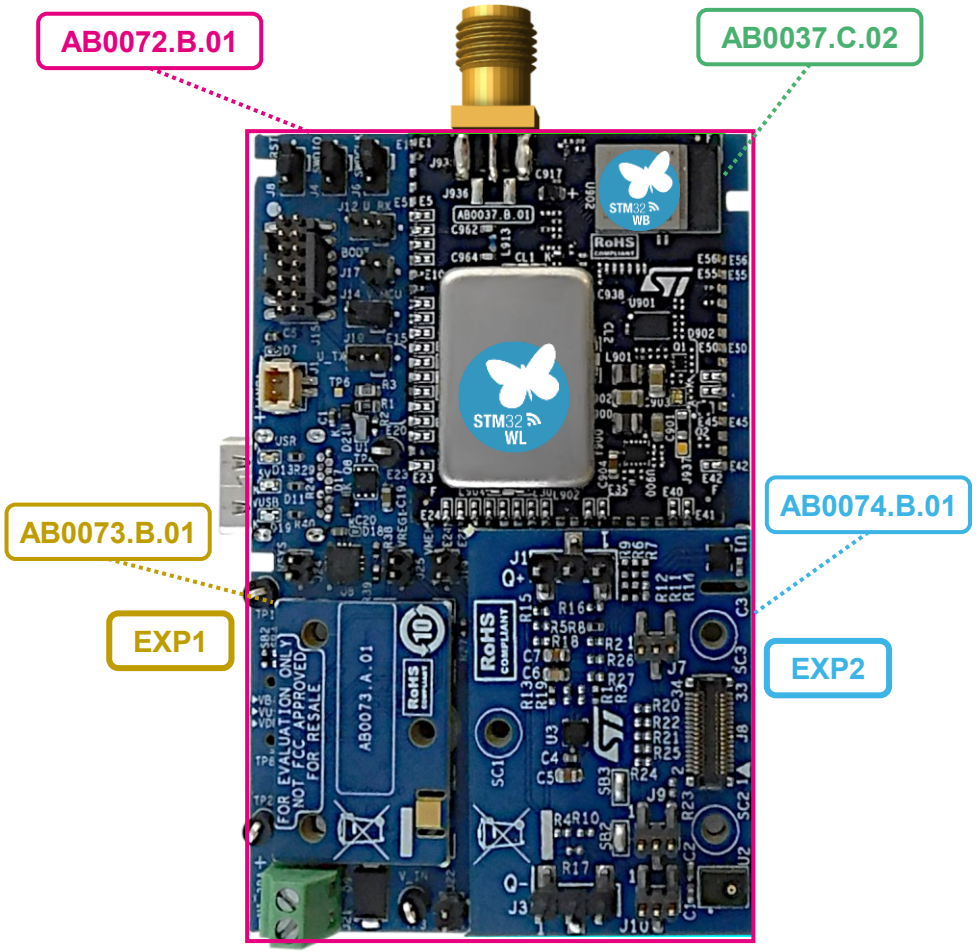
STDES-CBMLoRaBLE: Hardware description

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



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STDES-CBMLoRaBLE: Hardware details

TCPP01-M12
Single chip solution for USB Type-C port protection

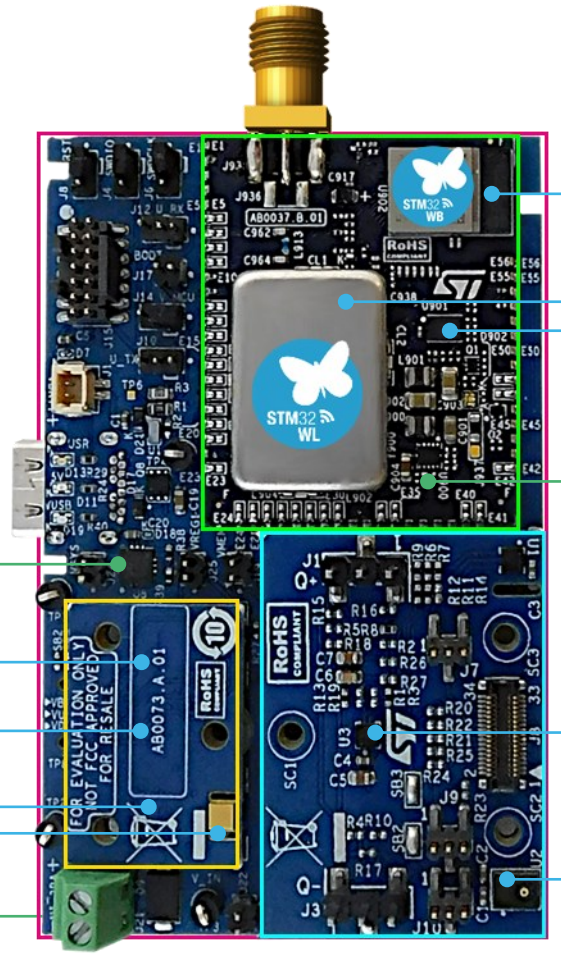
IIS2ICLX
High-accuracy, High-resolution, Low-power, 2-axis Digital Inclinometer with ML Core

IIS3DWB
Ultra-wide bandwidth, low-noise, 3-axis digital vibration sensor

ISM330DHCX
16g digital accelerometer and a digital gyroscope with ML Core

STTS22H
Low-voltage, ultra-low-power, 0.5 °C accuracy temperature sensor

L7983
12V – 48V , 300 mA synchronous step-down switching regulator



STM32WB5MMG
ultra-low-power, small form factor, certified 2.4GHz wireless module

STM32WL55JC
long range wireless and ultra-low-power microcontroller

STSAFE-A110
secure element which supports authentication and data secure management

ST1PS02
Nano-quiescent synchronous step-down converter

ILPS22QS
Dual full-scale, absolute digital barometer with **Qvar** embedded sensing (electrode compatible)

IMP34DT05
MEMS audio sensor omnidirectional digital microphone for industrial applications

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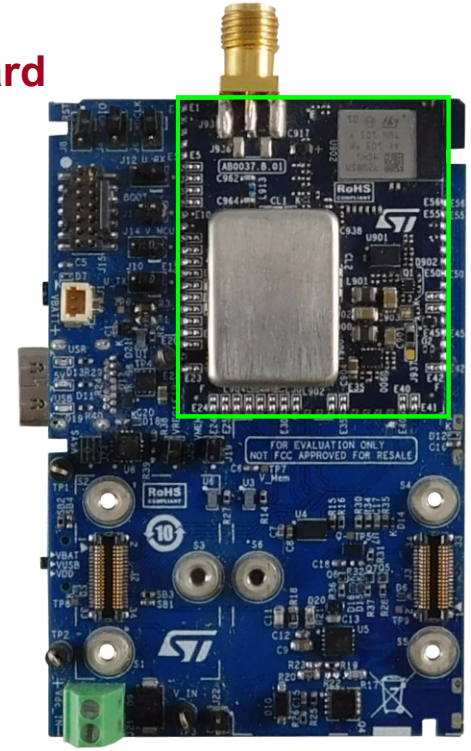
STDES-CBMLoRaBLE: Kit details & assembly solutions

Antenna

Main Board

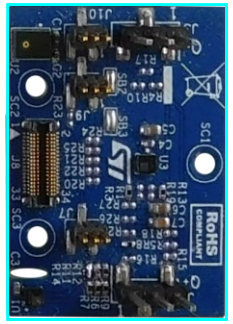


SB Module
STM32WB
+
STM32WL

EXP1

IIS3DWB
ISM330DHCX
IIS2ICLX
STTS22HH

EXP2



ILPS22QSTR
IMP34DT05A

Scenario 1
All boards stacked

Scenario 2
EXP1 displaced EXP2 Stacked

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STDES-CBMLoRaBLE: System Setup

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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:

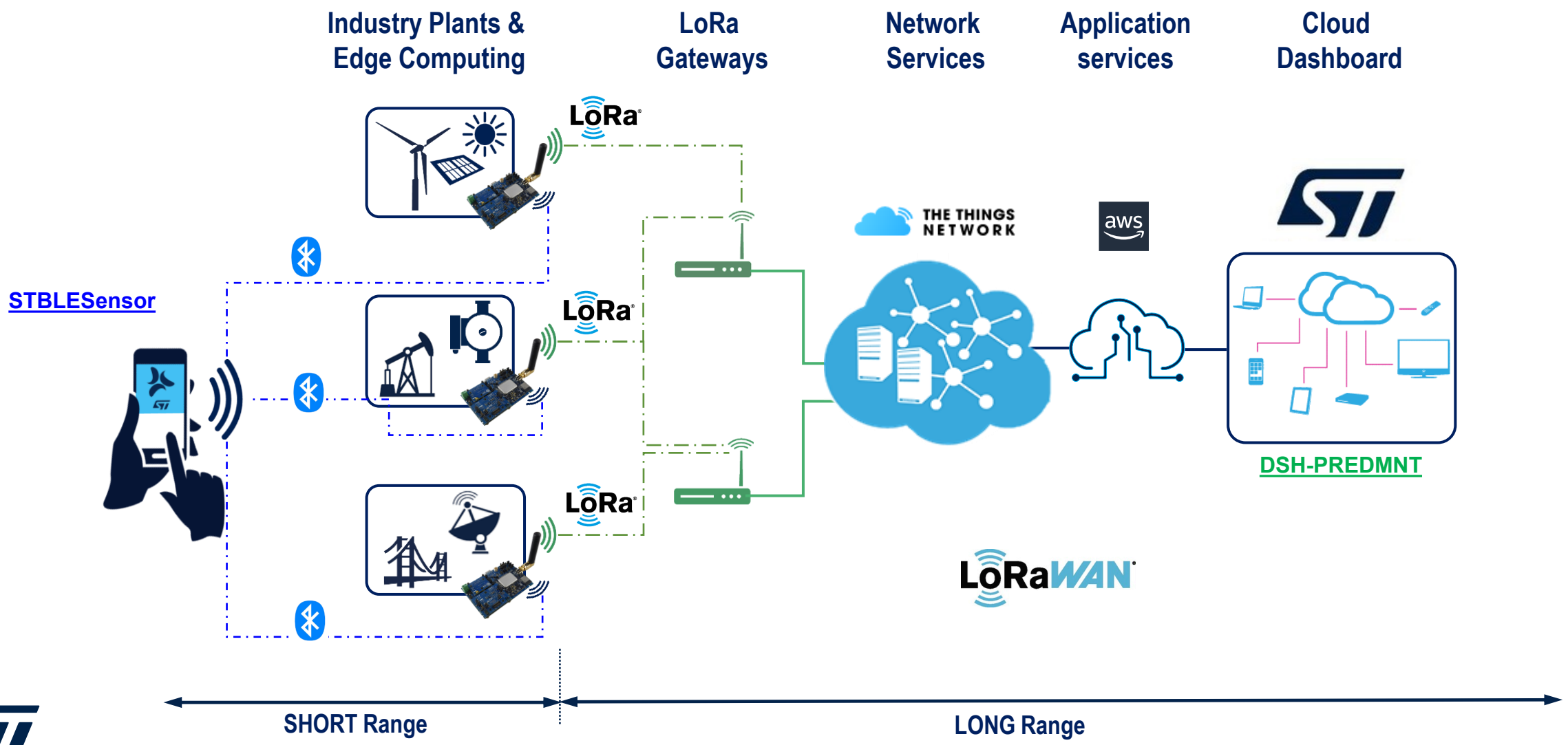
- **DSH-PREDMNT AWS Dashboard** – Remote monitoring

  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

STDES-CBMLoRaBLE IIoT Nodes in Industry Plants

STDES-CBMLoRaBLE
STSW-CBMLoRaBLE

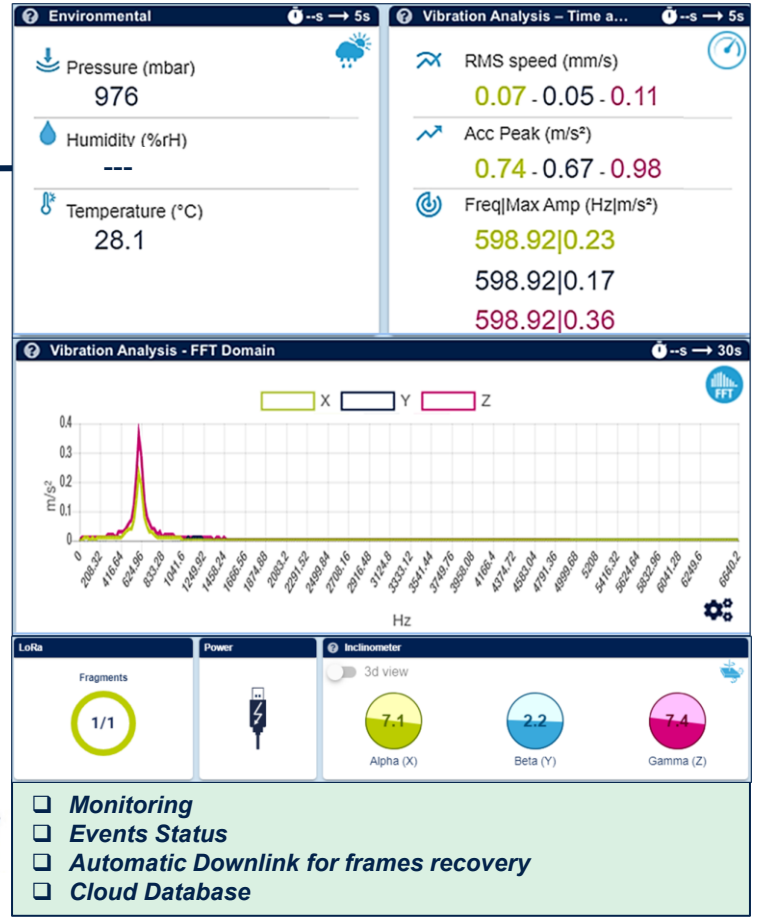
LoRaWAN

LoRa Gateway

Network Server

Network Adapter

DSH-PREDMNT AWS Dashboard



- ❑ *Monitoring*
- ❑ *Events Status*
- ❑ *Automatic Downlink for frames recovery*
- ❑ *Cloud Database*

ST BLE Sensor App

- ❑ *Monitoring & Processing settings*
- ❑ *Status check*
- ❑ *LoRa Commands*
- ❑ *LoRa parameters setting*

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STSW-CBMLoRaBLE: Firmware Overview

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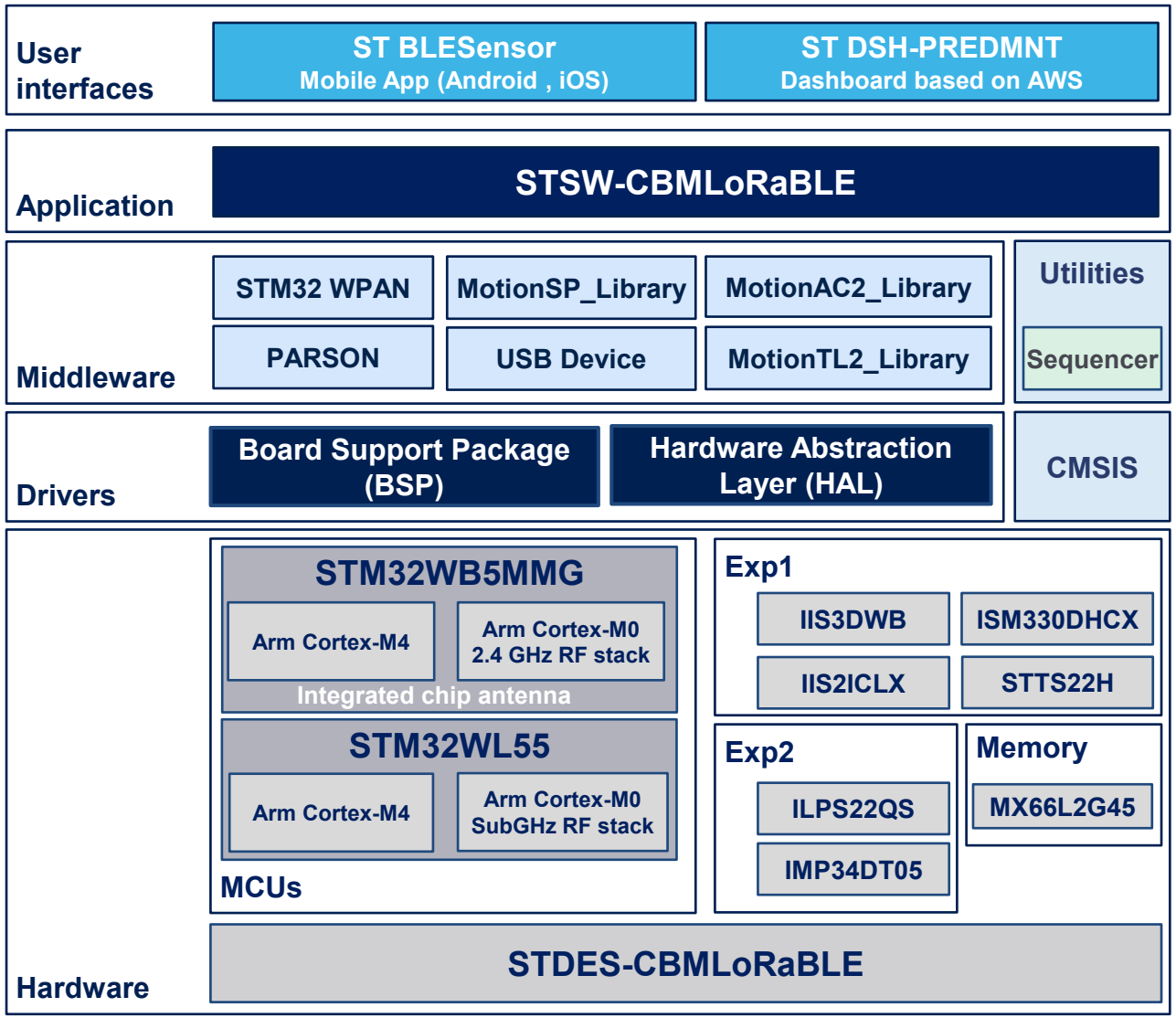
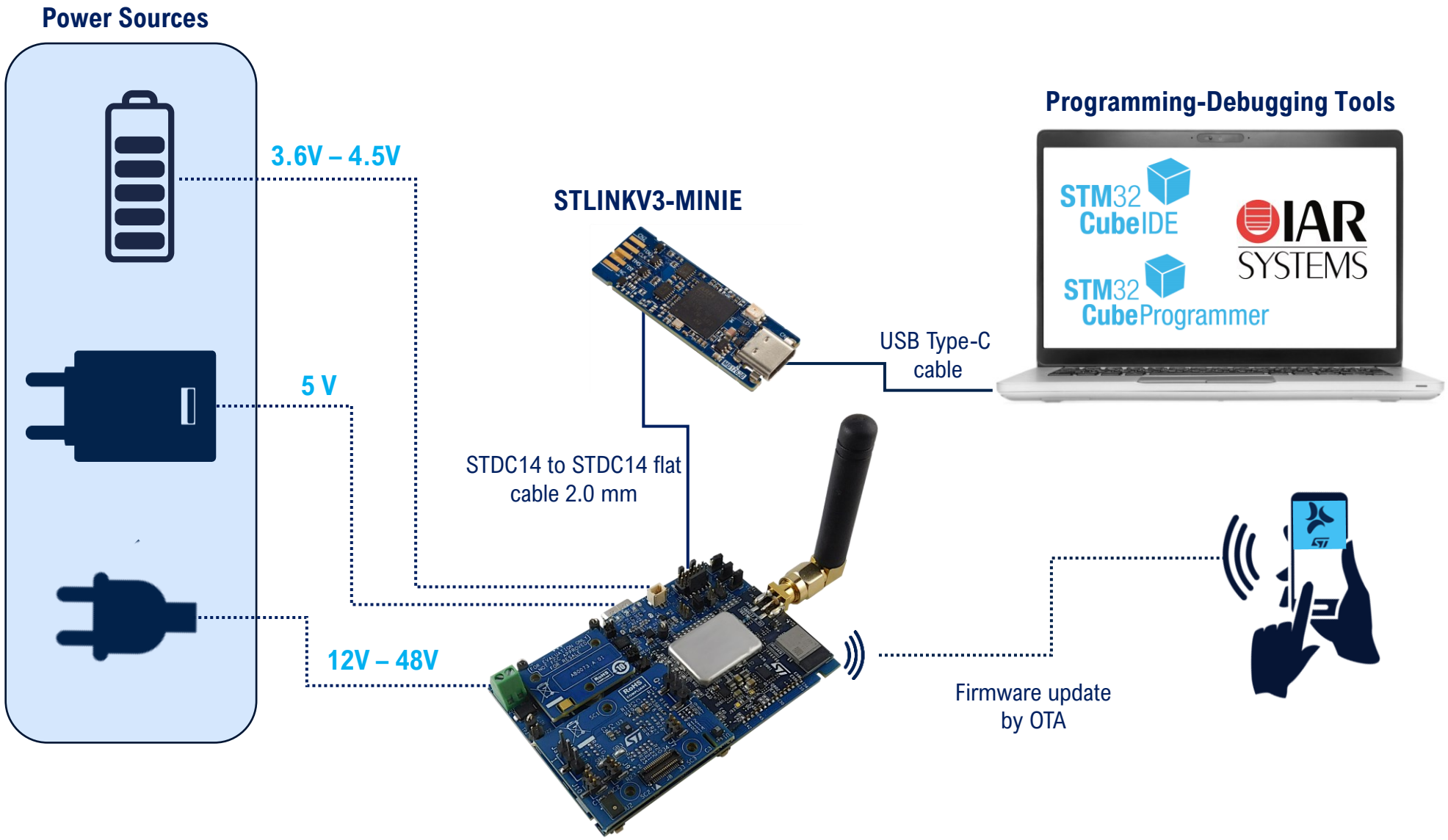
Firmware architecture based on Sequencer



Power options, programming connections and Firmware update by OTA



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STSW-CBMLoRaBLE: Embedded Processing

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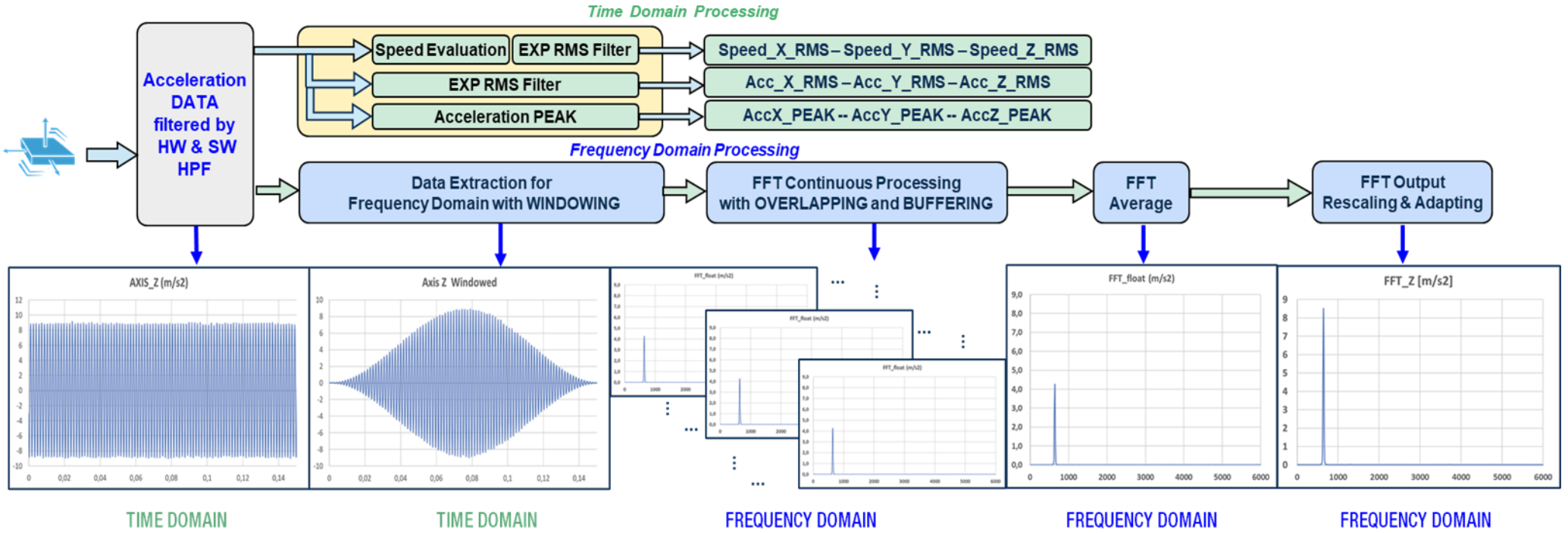
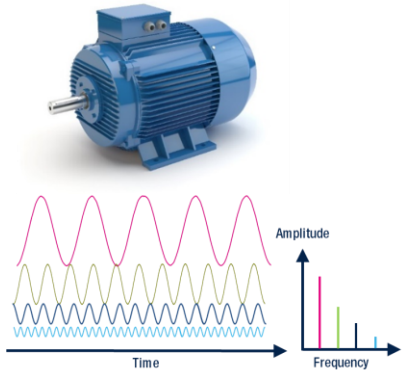
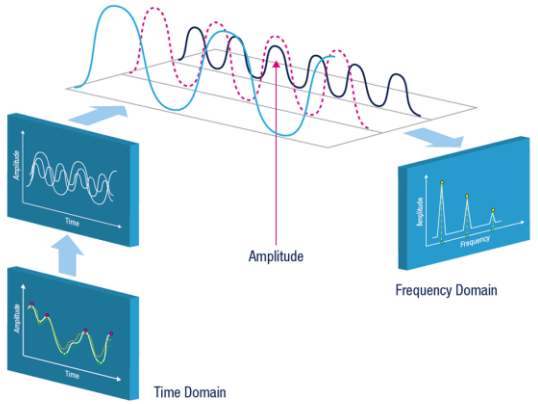
Time and Frequency domain analysis with **MotionSP**



❑ 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

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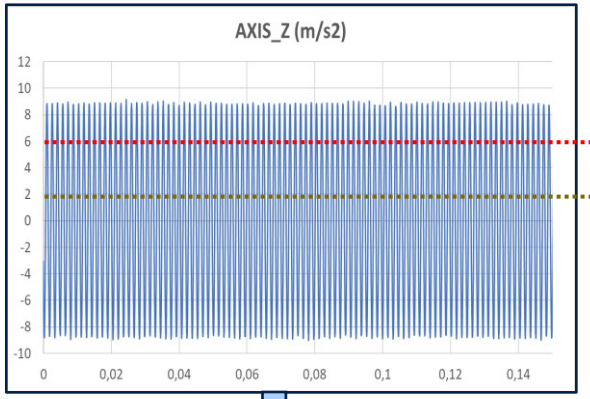
Predictive Maintenance Status Messages

❑ Time Domain Analysis:

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



Alarm Thresholds

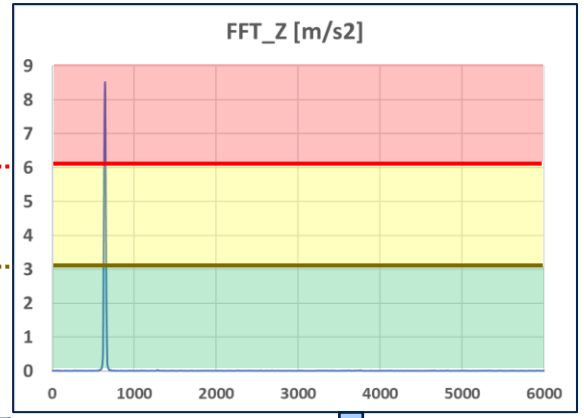
Warning Thresholds

Speed RMS (X,Y,Z) [mm/s]	Comparison	Time DomainThresholds
		Speed RMS_THR (X,Y,Z)
Acc PEAK (X,Y,Z) [m/s^2]		Acc PEAK_THR (X, Y, Z)

Time Domain Status Evaluation	
Speed RMS (X,Y,Z) **STATUS**	GOOD - WARNING - ALARM
Acc PEAK (X,Y,Z) **STATUS**	GOOD - WARNING - ALARM

❑ Frequency Domain Analysis:

- FFT max amplitude evaluation and comparison with thresholds



Alarm Thresholds

Warning Thresholds

Alarm Area

Warning Area

Good Area

Frequency Domain Thresholds	Comparison	FFT Max Ampl (X,Y,Z) [m/s^2]
FFT_Amplitude_THR (X,Y,Z)		Freq_XYZ [Hz]

Frequency Domain Status Evaluation	
FFT Max Amplitudes (X,Y,Z) [m/s^2]	GOOD - WARNING - ALARM
FFT Frequencies [Hz]	

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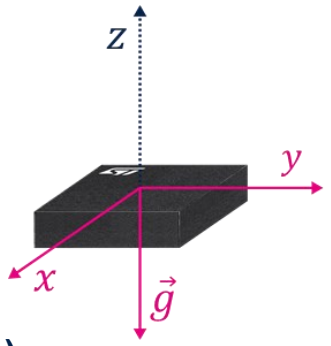
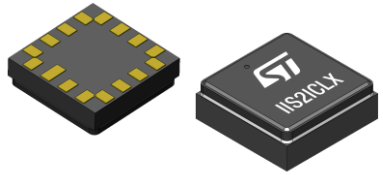
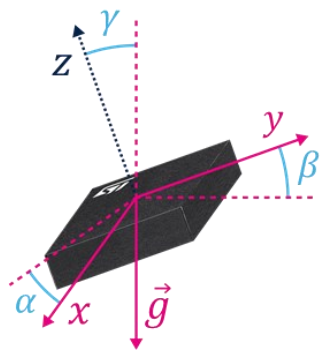
Inclination measurement

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.

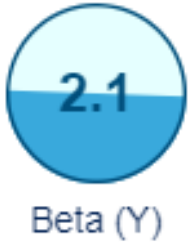




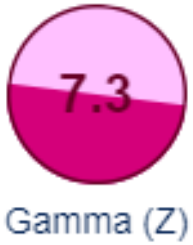


Alpha → α

Beta → β



Gamma → γ



(*) *For this purpose, the package embeds the **MotionAC2_Library & MotionTL2_Library***

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STSW-CBMLoRaBLE: LoRa Dynamic Frames

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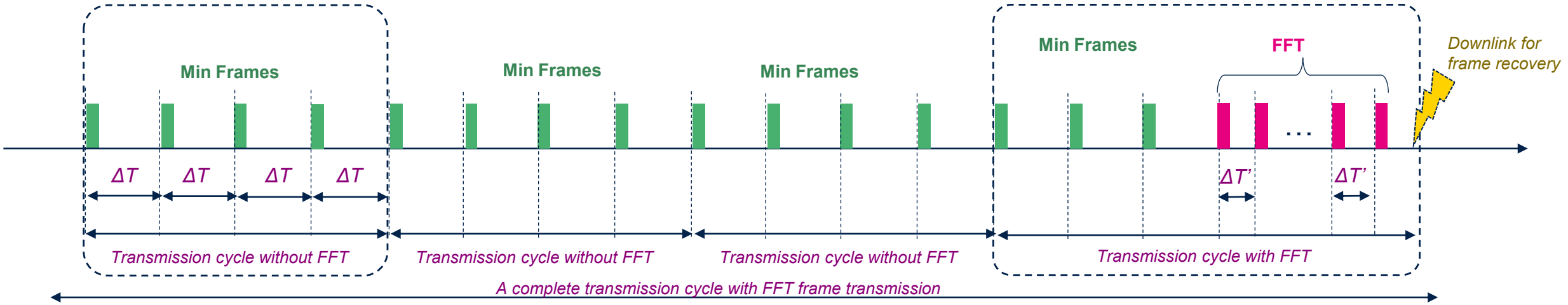
Frames transmission scheme



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 trasmission 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*

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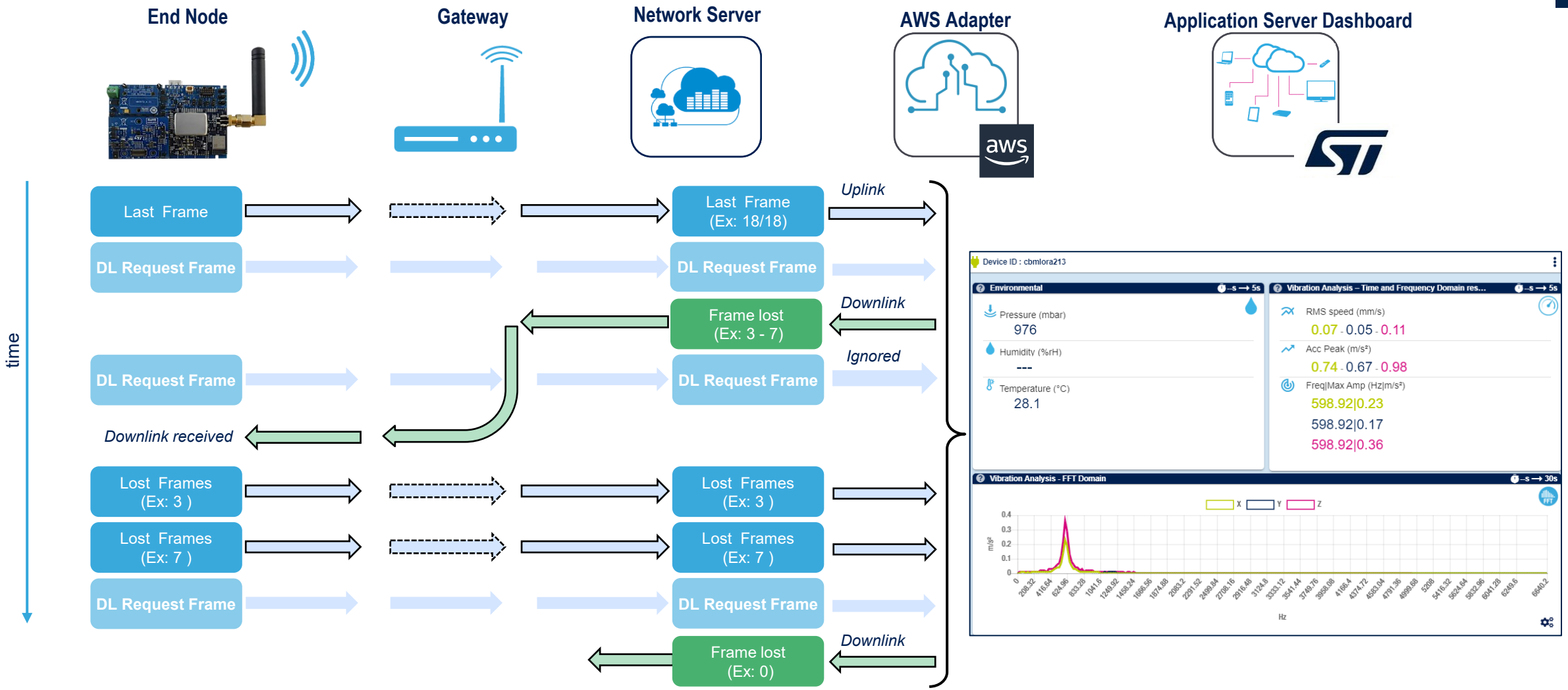
STDES-CBMLoRaBLE LoRaWAN architecture



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

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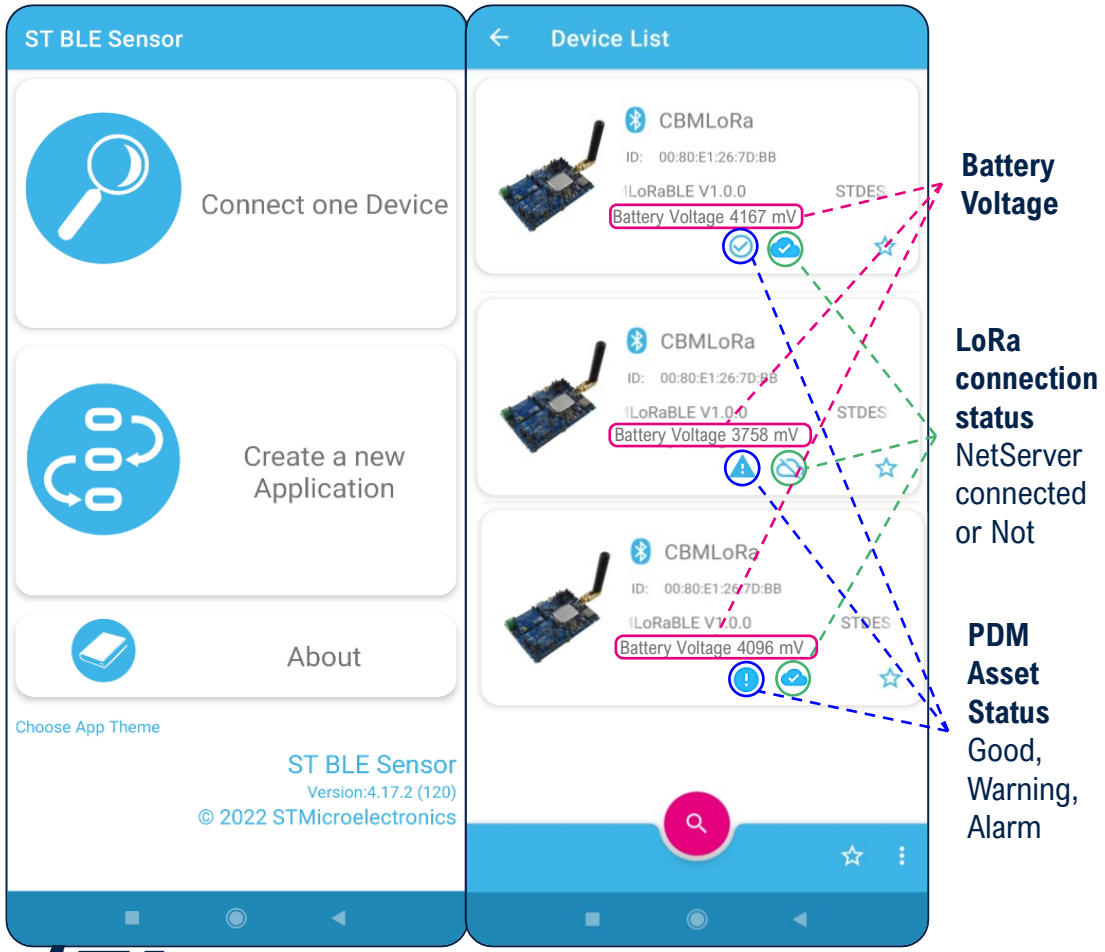
Using the BLE Mobile App

STBLESensor mobile app for Android and iOS

BLE Sensor App information in advertising

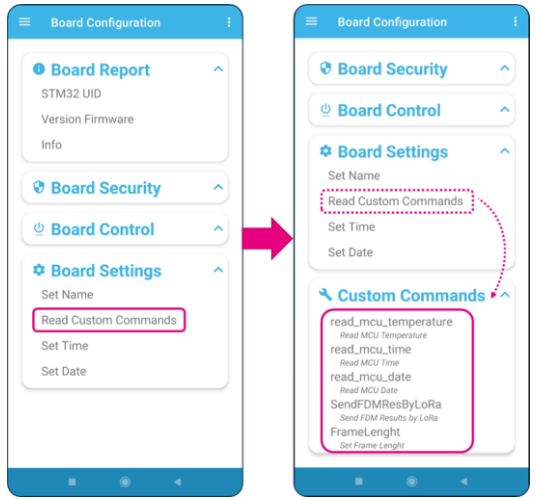


Battery Voltage

LoRa connection status NetServer connected or Not

PDM Asset Status Good, Warning, Alarm

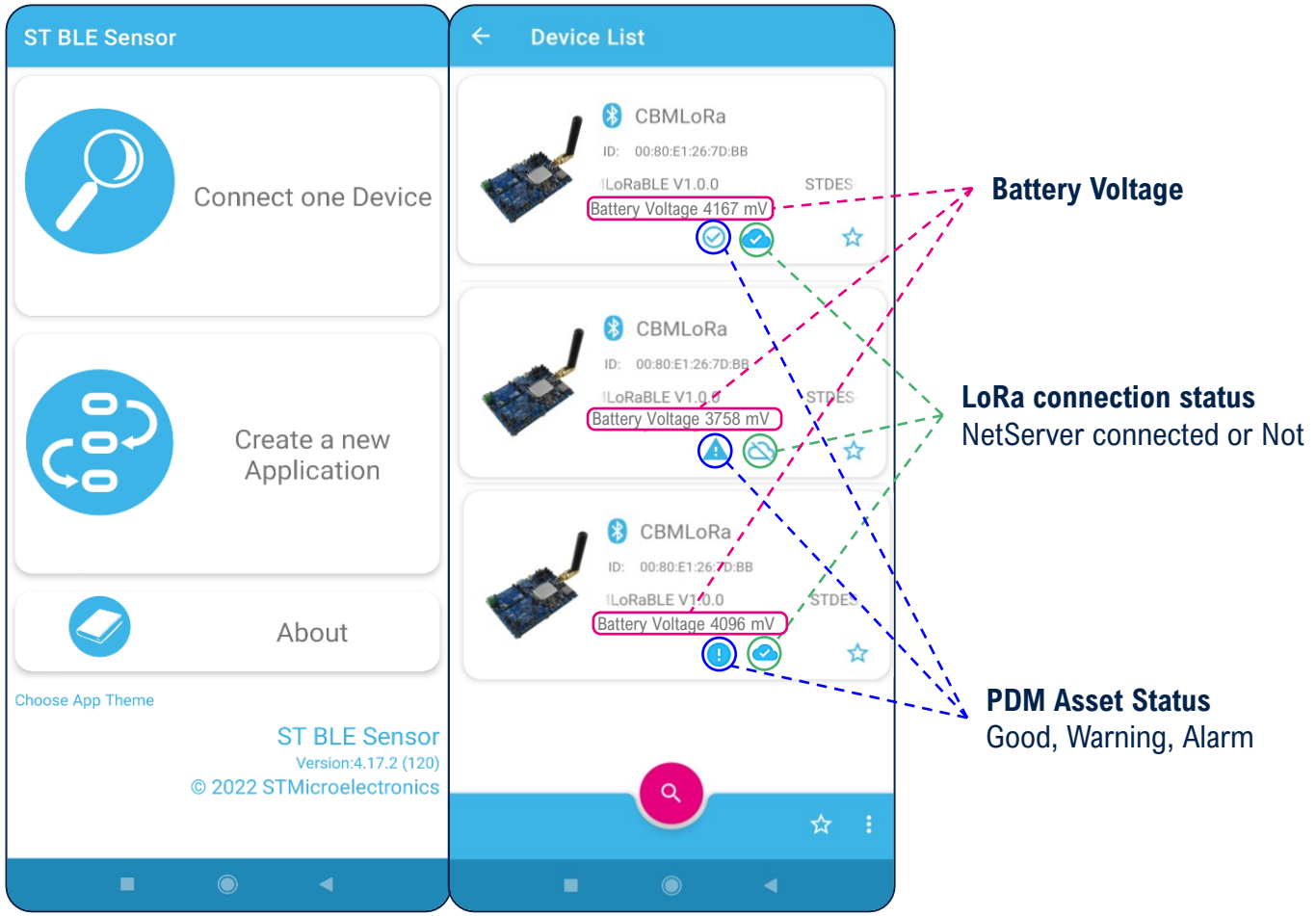
Environmental, FFT, Plot Data, and Predictive Maintenance Panels



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

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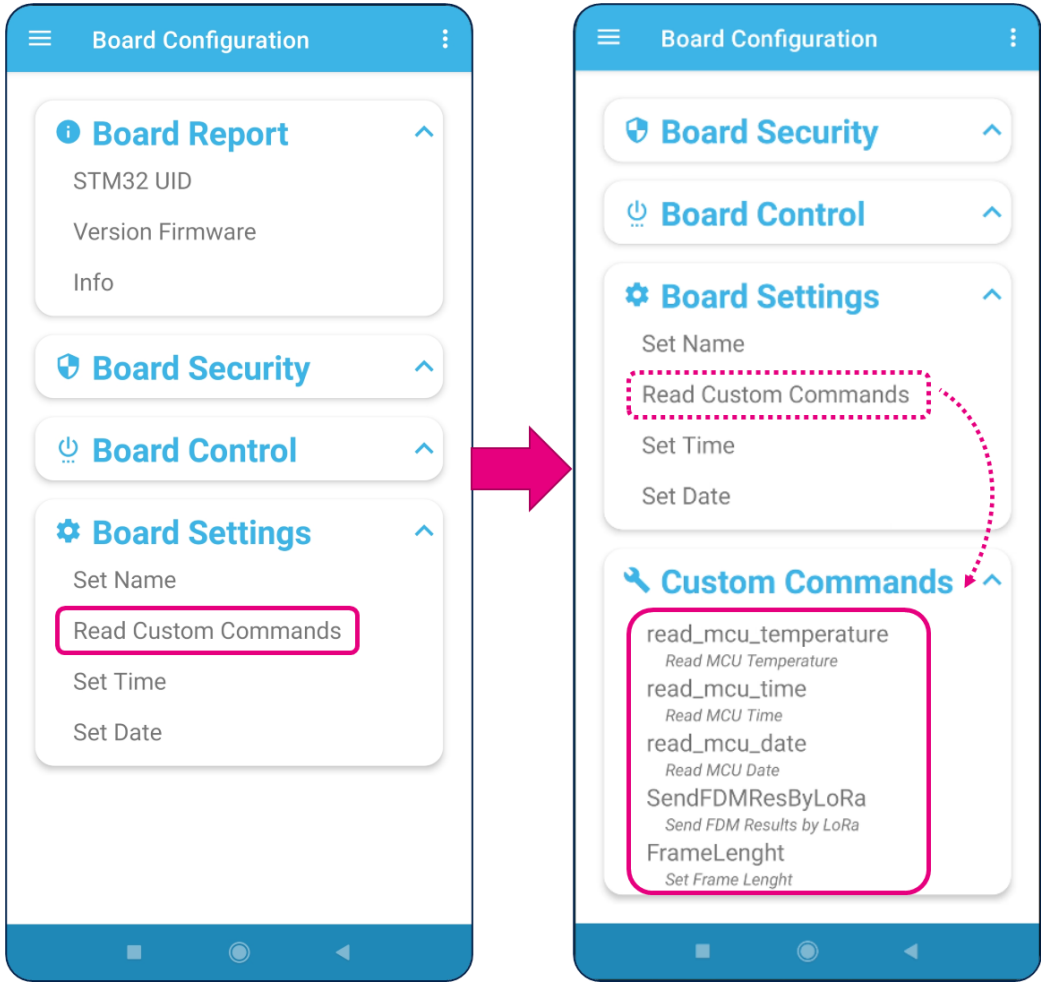
STBLESensor mobile app for Android and iOS

Use Custom Commands to control LoRa transmission

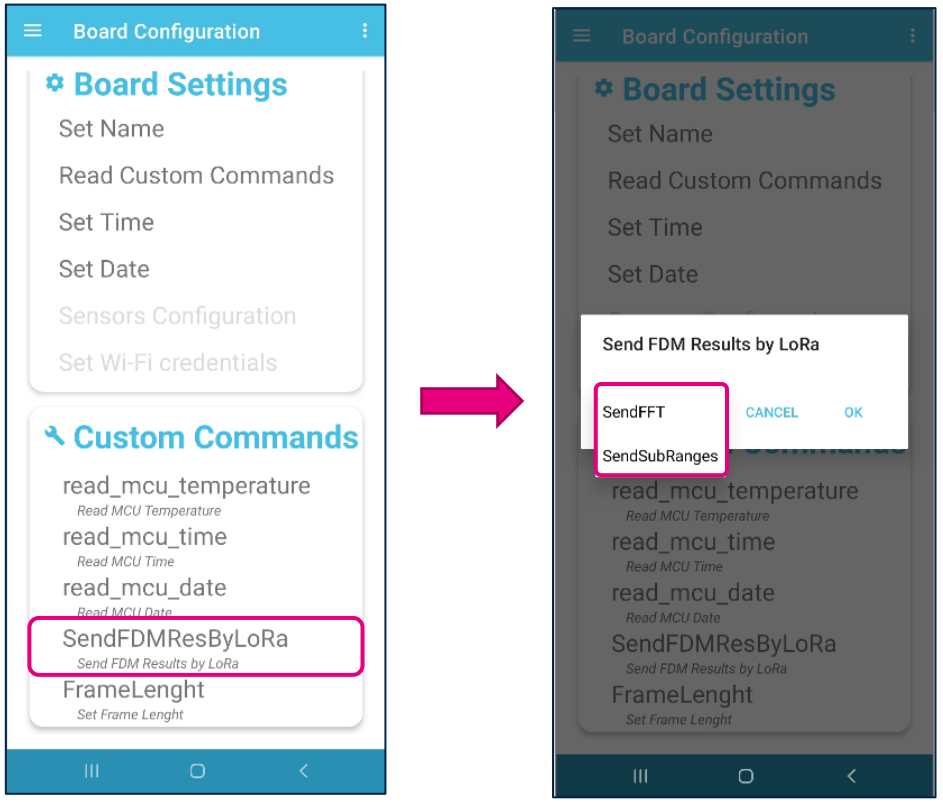
Open the **Board Configuration** demo window and scrolling down access to the Board Settings panel.

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**



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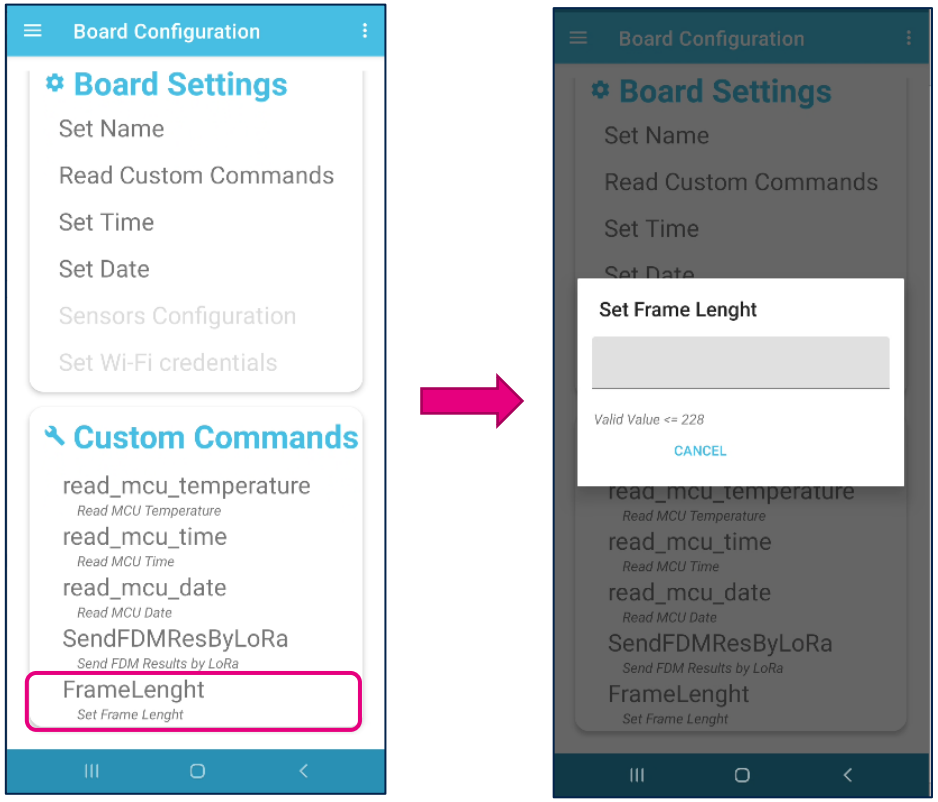
Read Custom Commands (2/2)

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

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Using the Predictive Maintenance Dashboard

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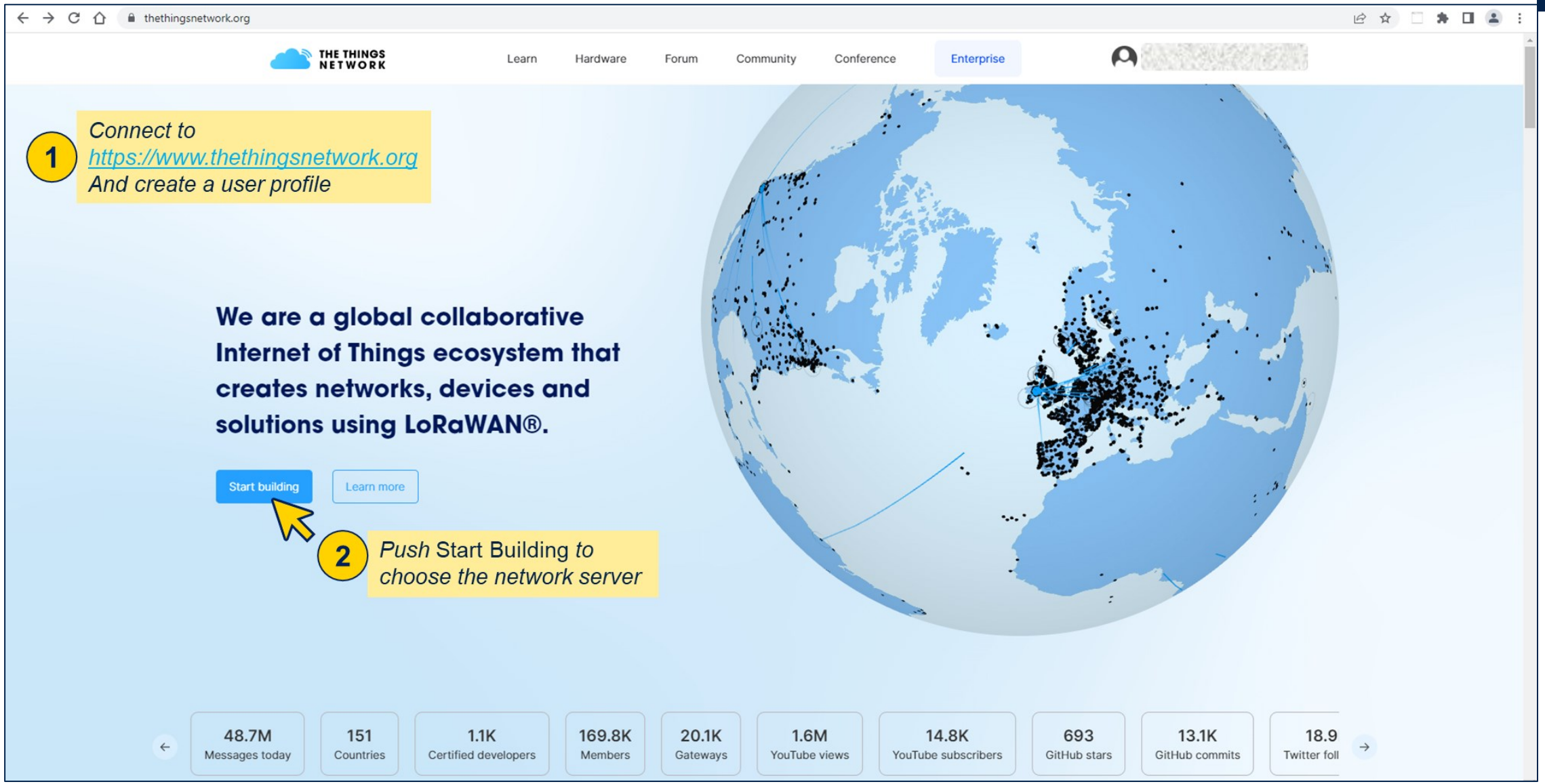
Create a profile on TTN network server



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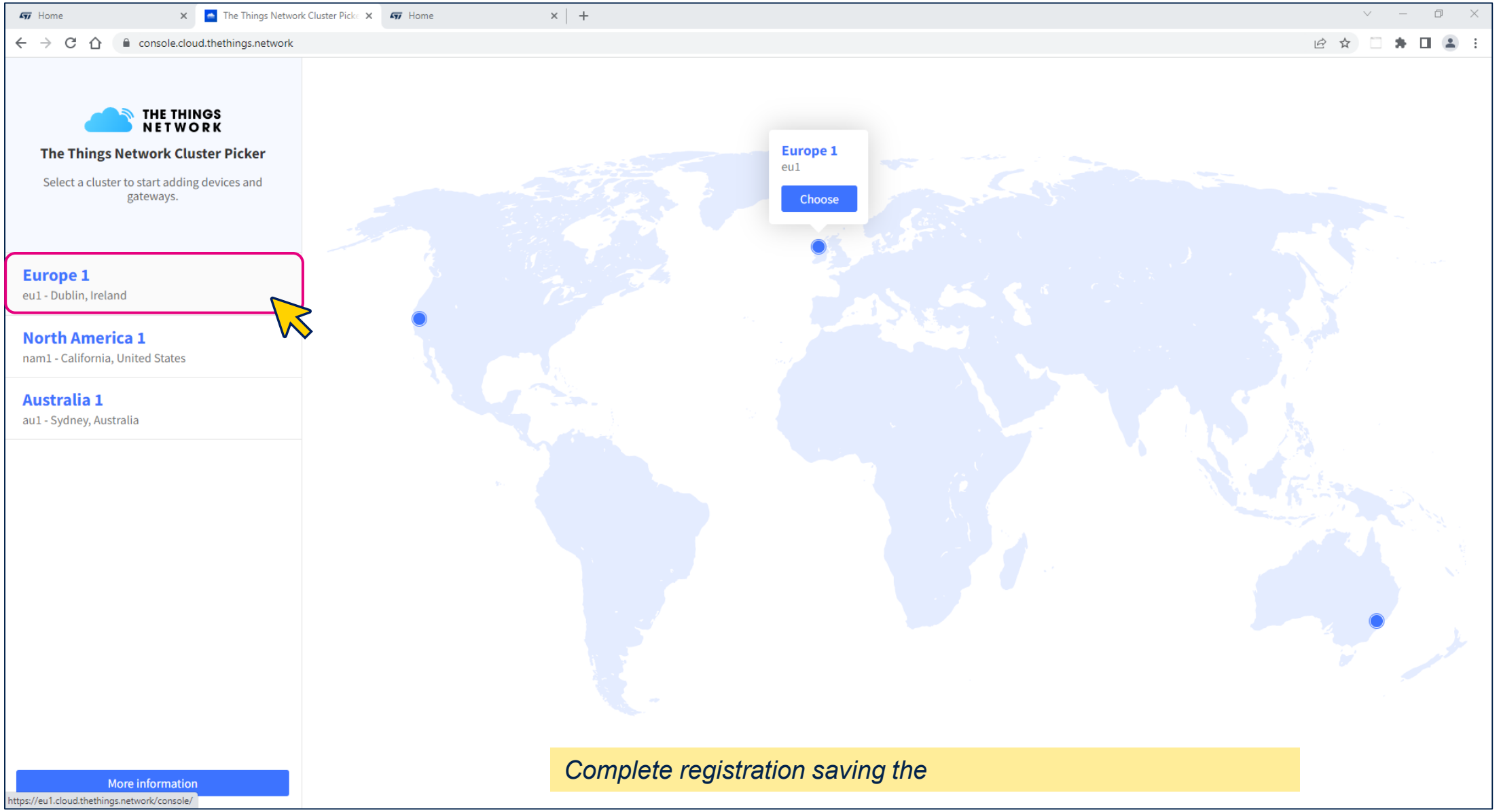
Select Europe cluster in TTN network



Complete registration saving the

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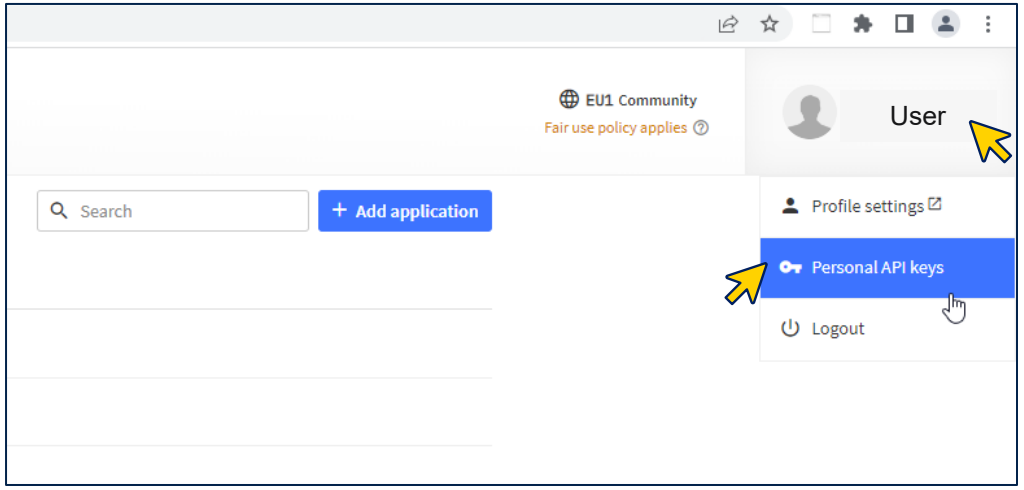
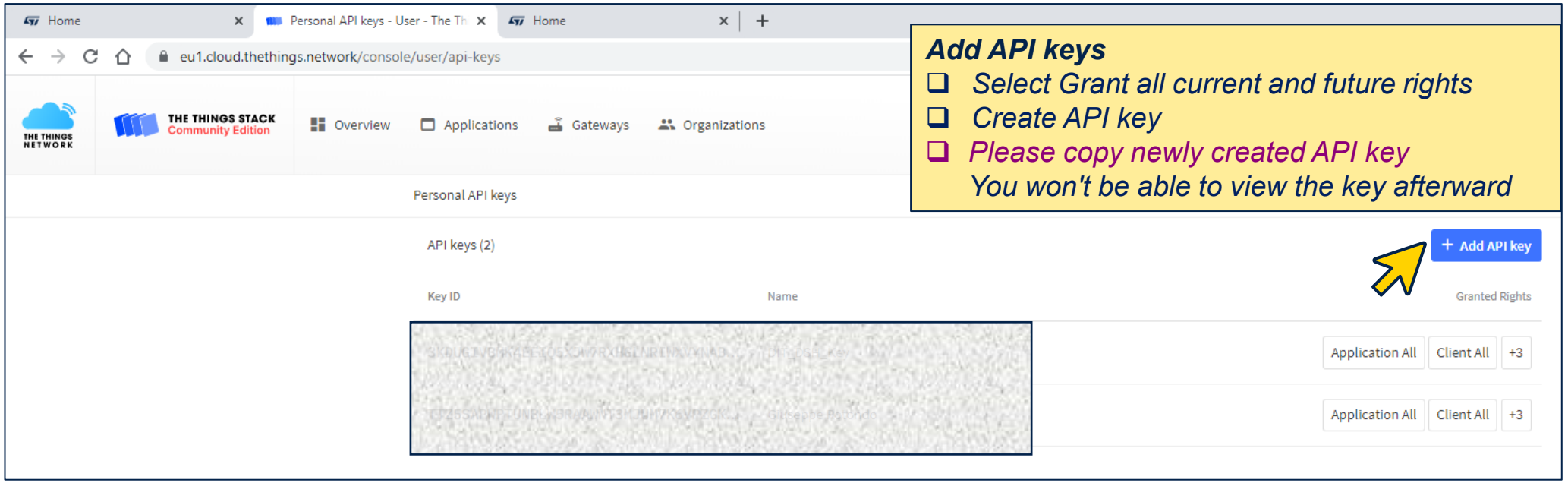
Generate an API User key



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



Add API keys
- ❑ *Select Grant all current and future rights*
- ❑ *Create API key*
- ❑ *Please copy newly created API key*
  You won't be able to view the key afterward

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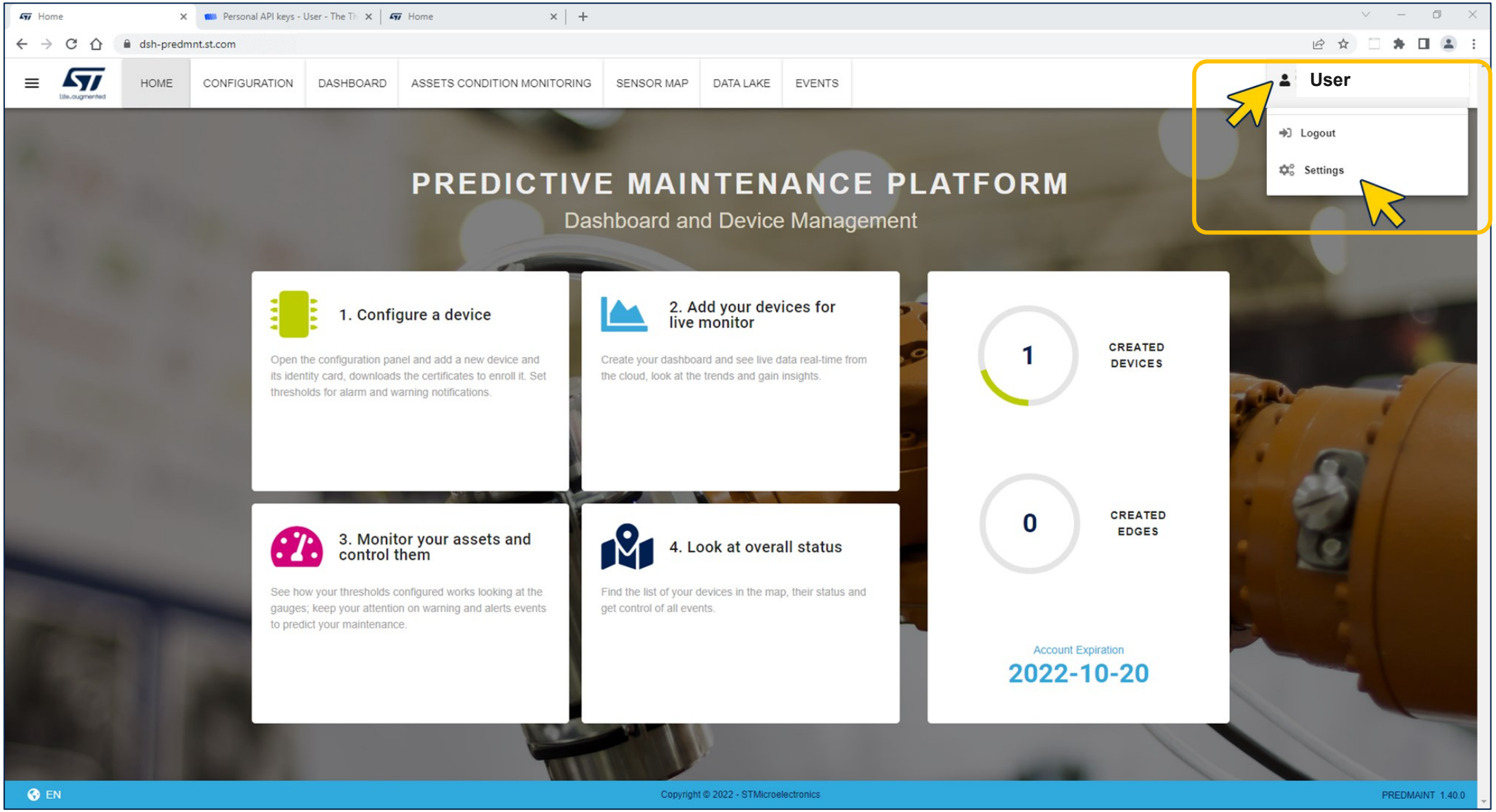
Create a user profile on ST DSH-PREDMNT



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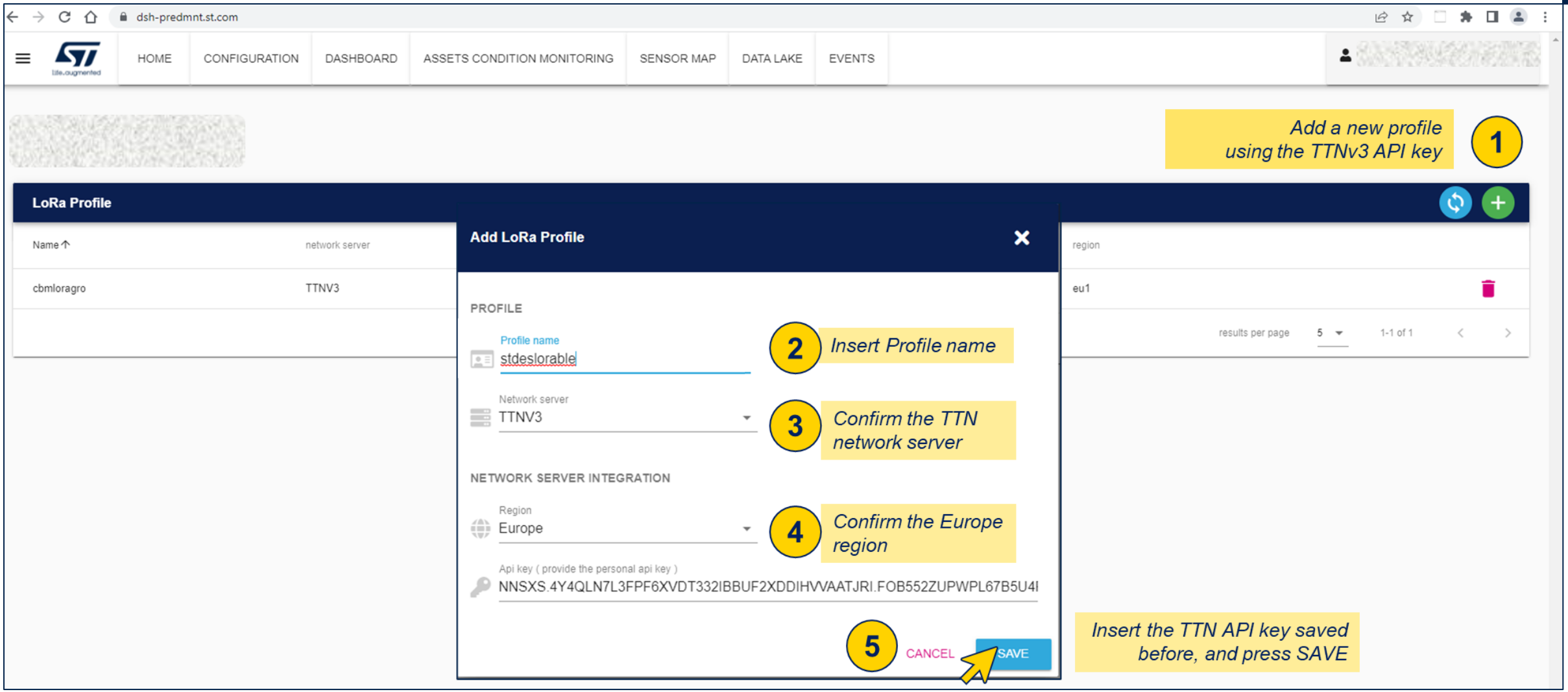
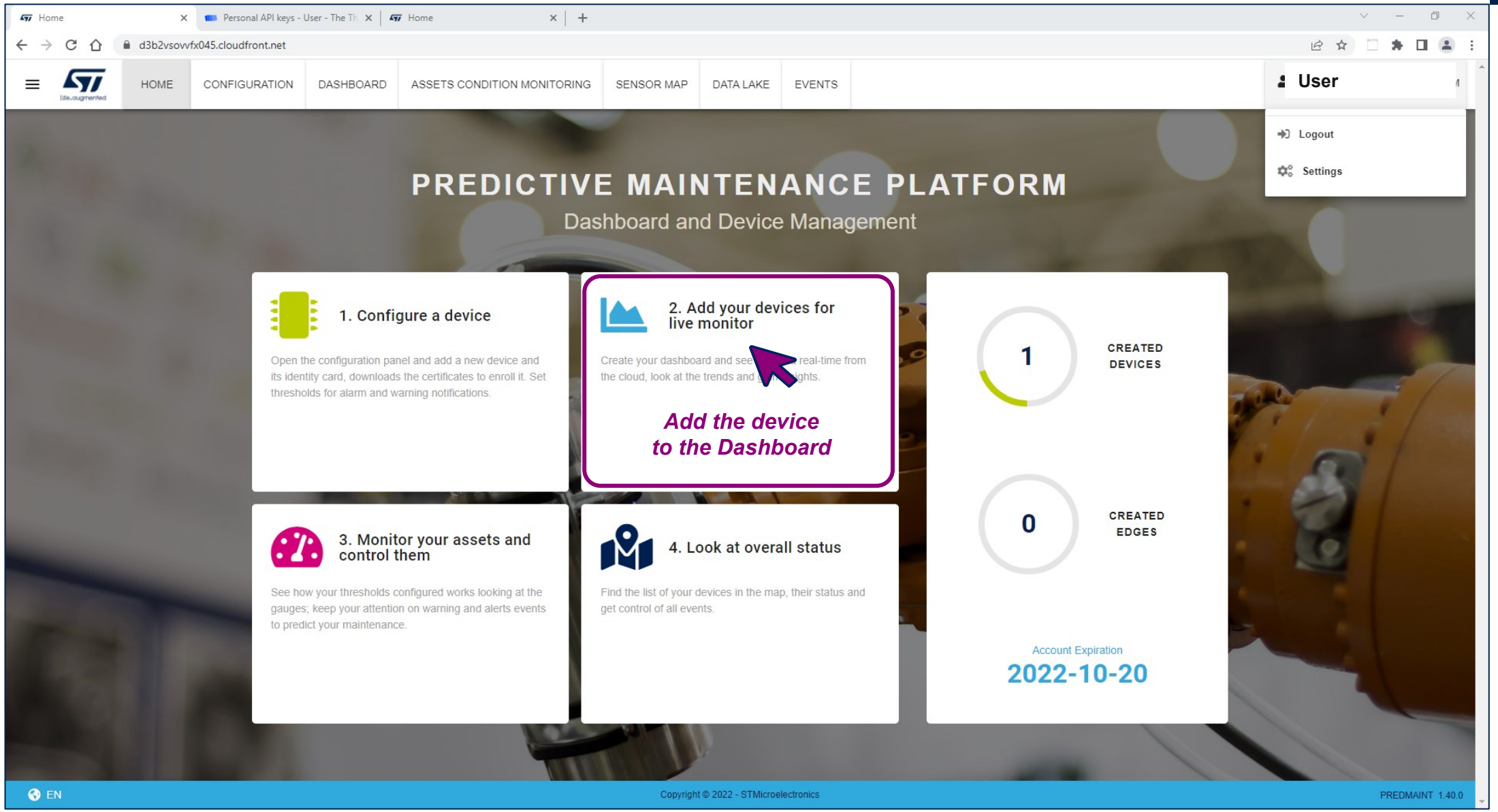
Add your LoRa application profile in Dashboard settings



Add your LoRa device in the dashboard



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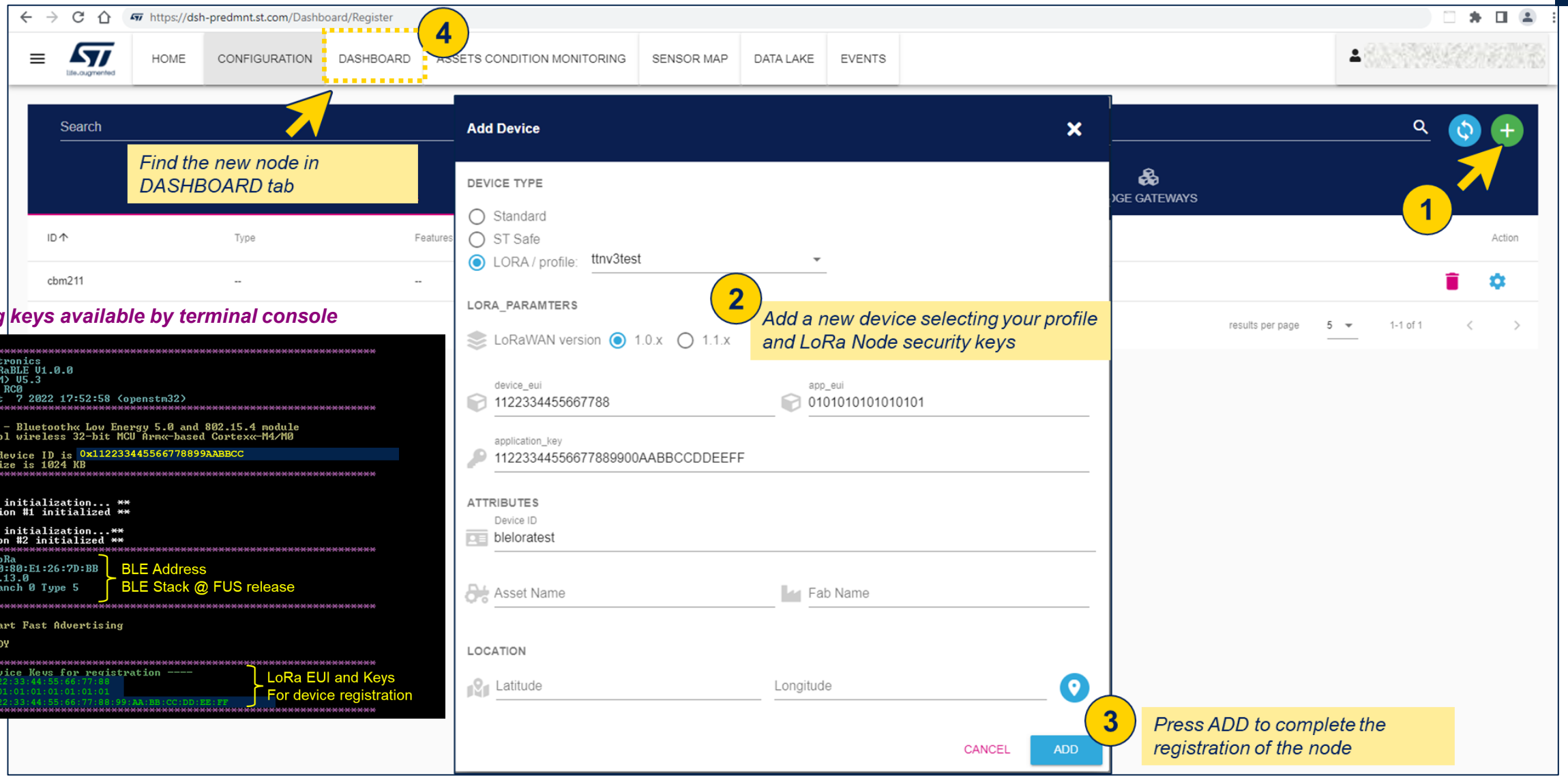
Add your LoRa device in Dashboard



Provisioning keys available by terminal console

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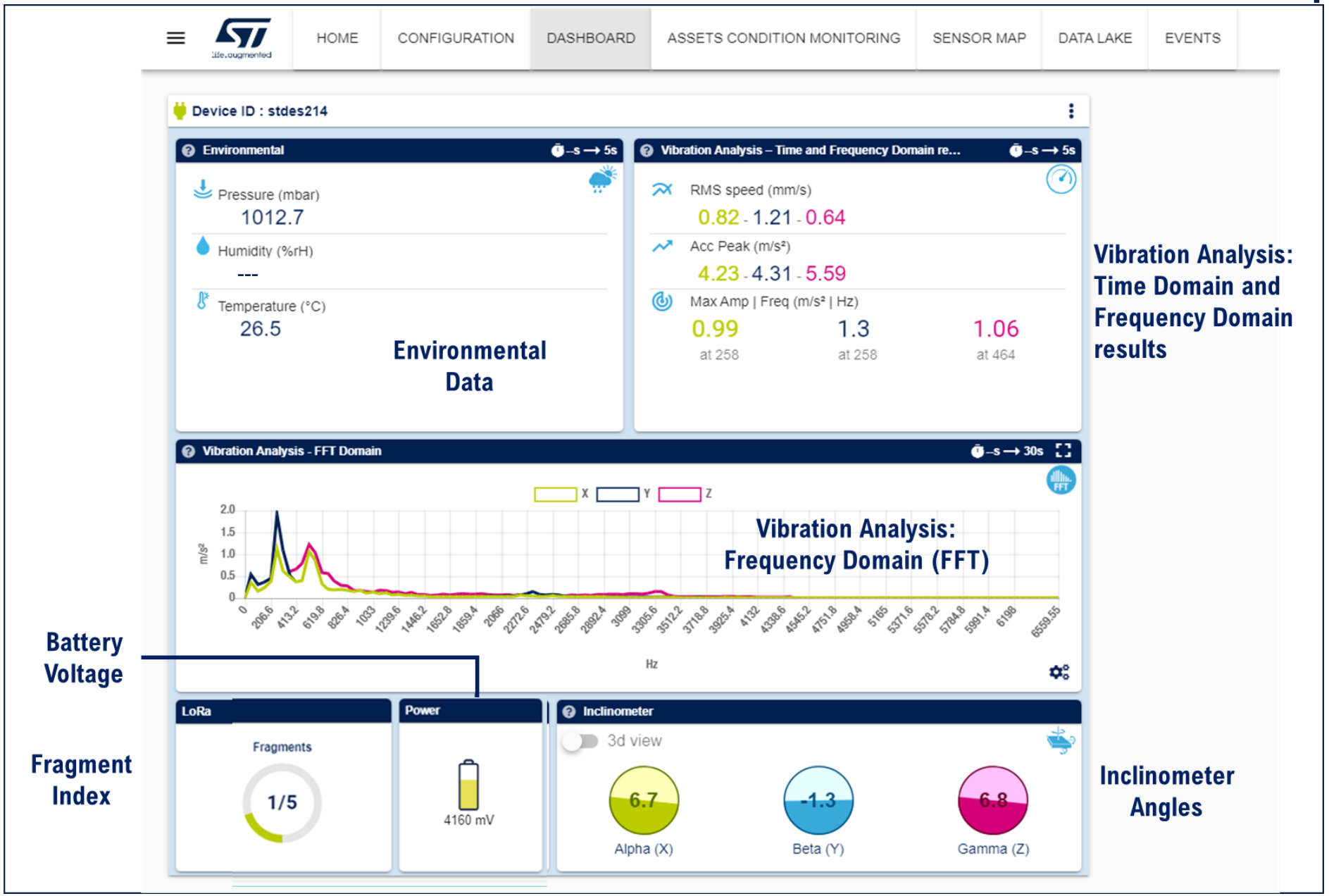
DSH-PREDMNT main page



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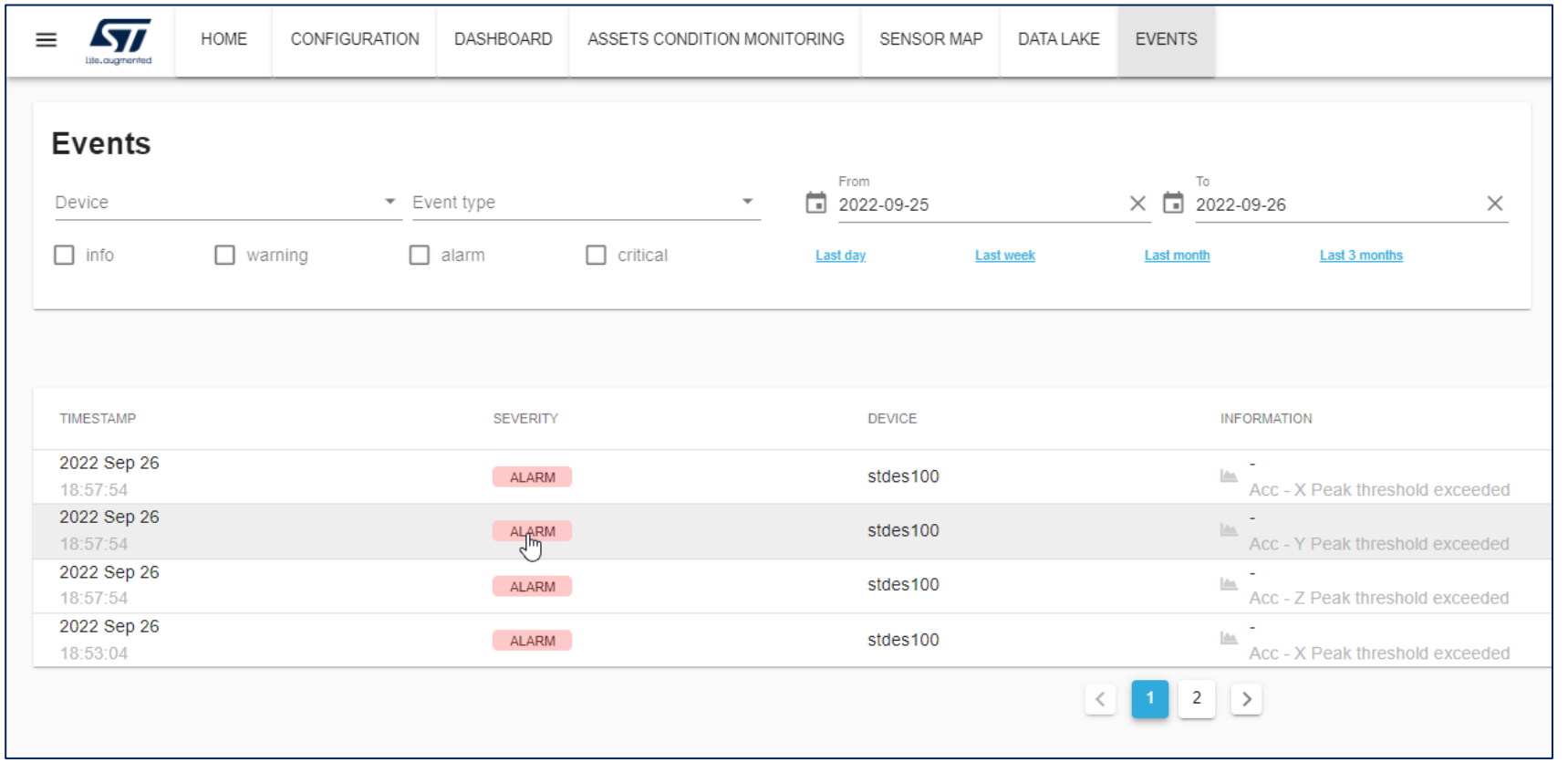
DSH-PREDMNT Events page



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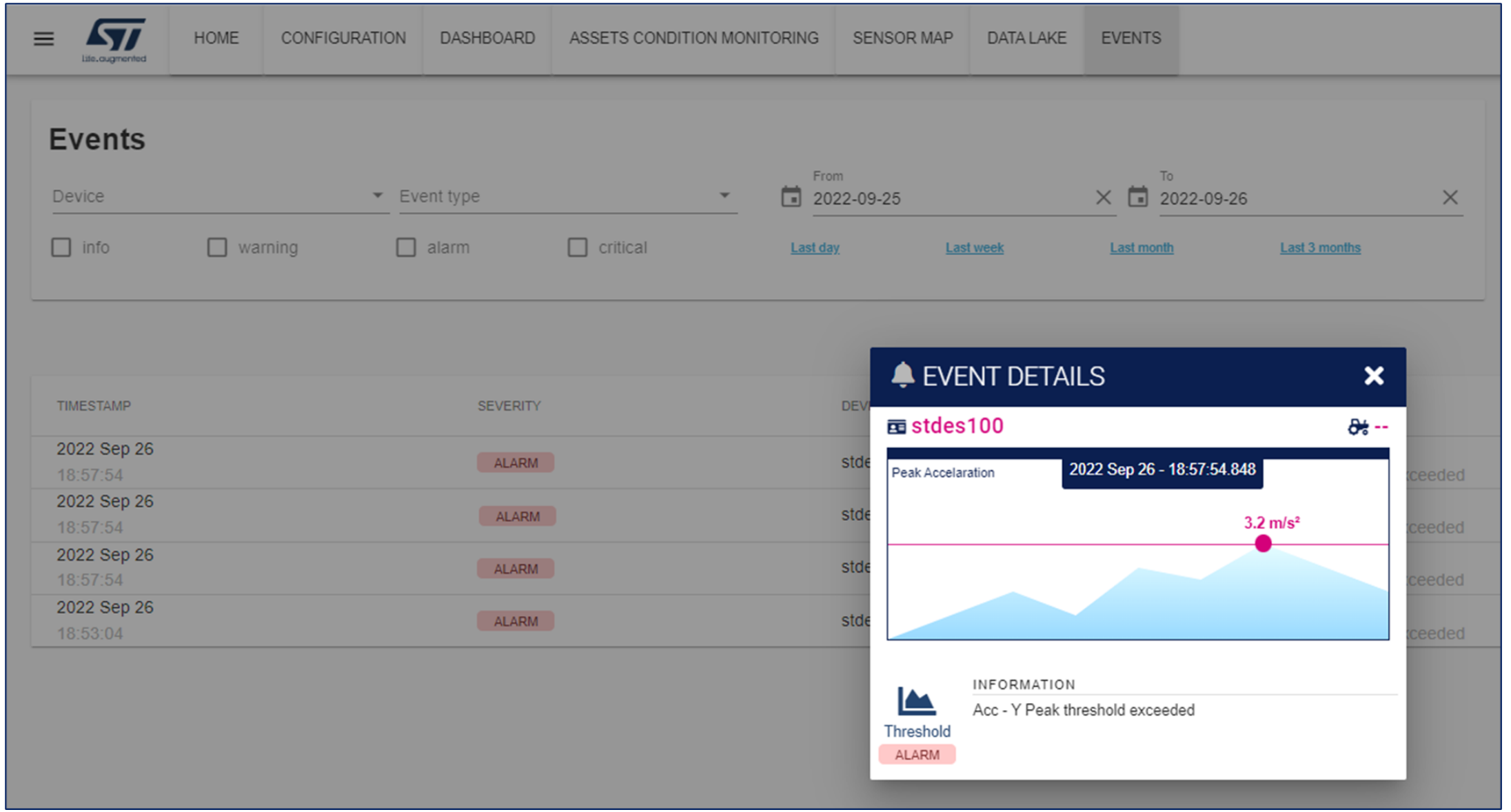
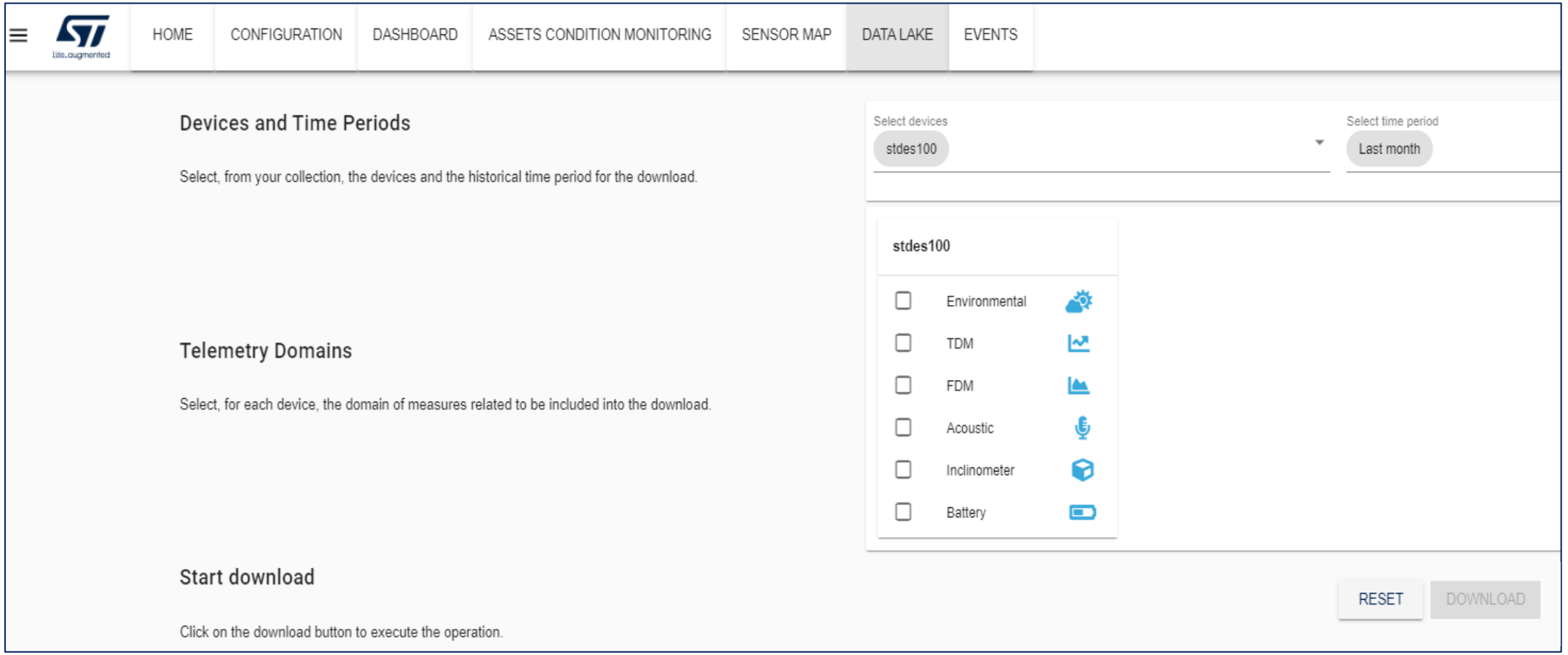
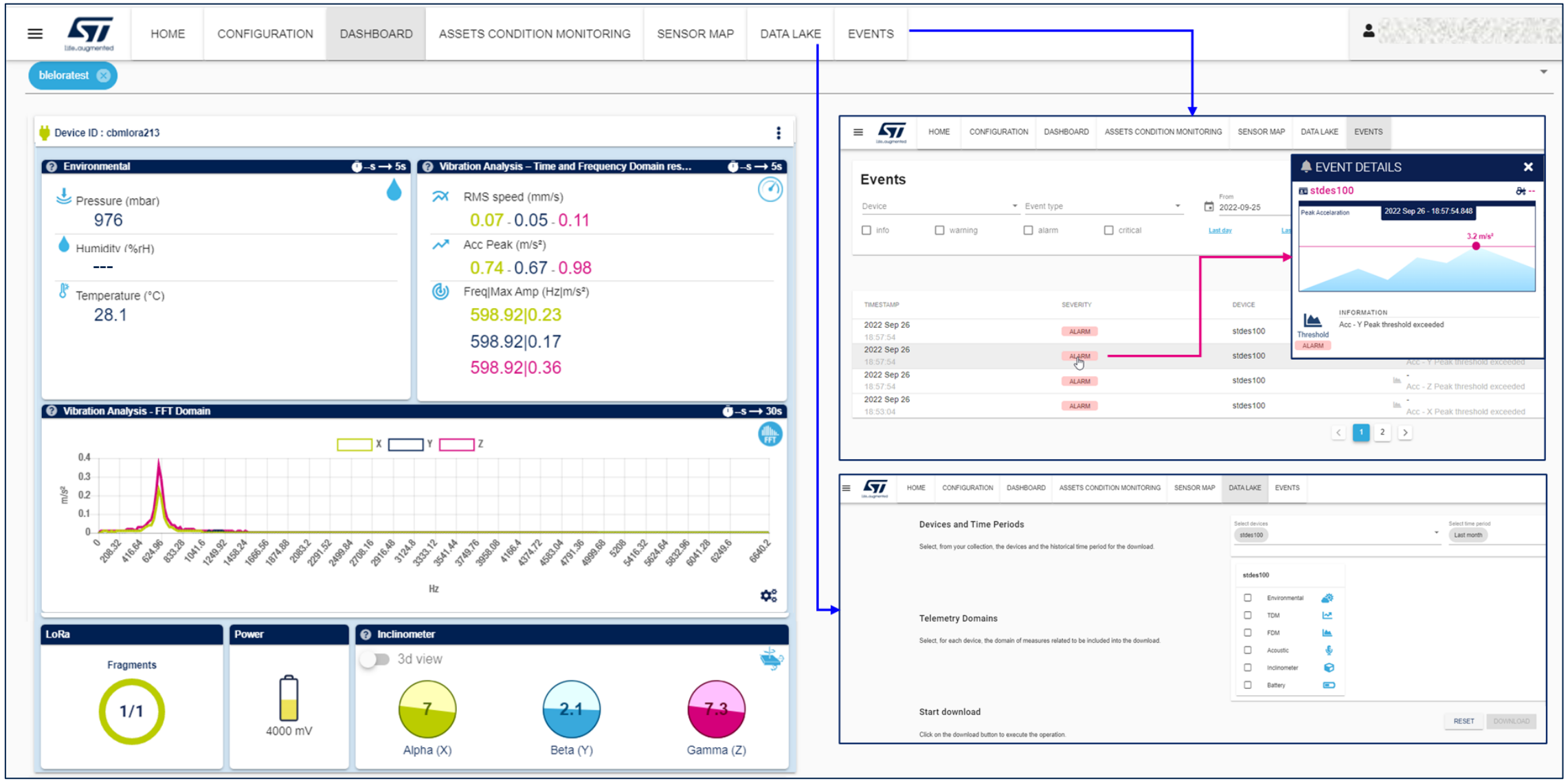
Open every events to understand the root cause



DSH-PREDMNT DATA LAKE page



ST DSH PREDMNT: Live Data, Events and Data Lake



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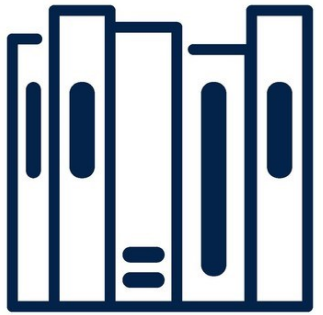
References

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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