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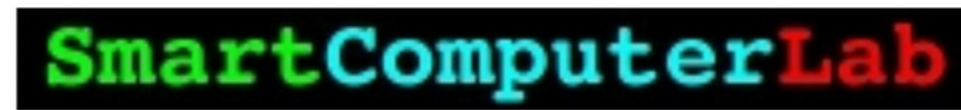
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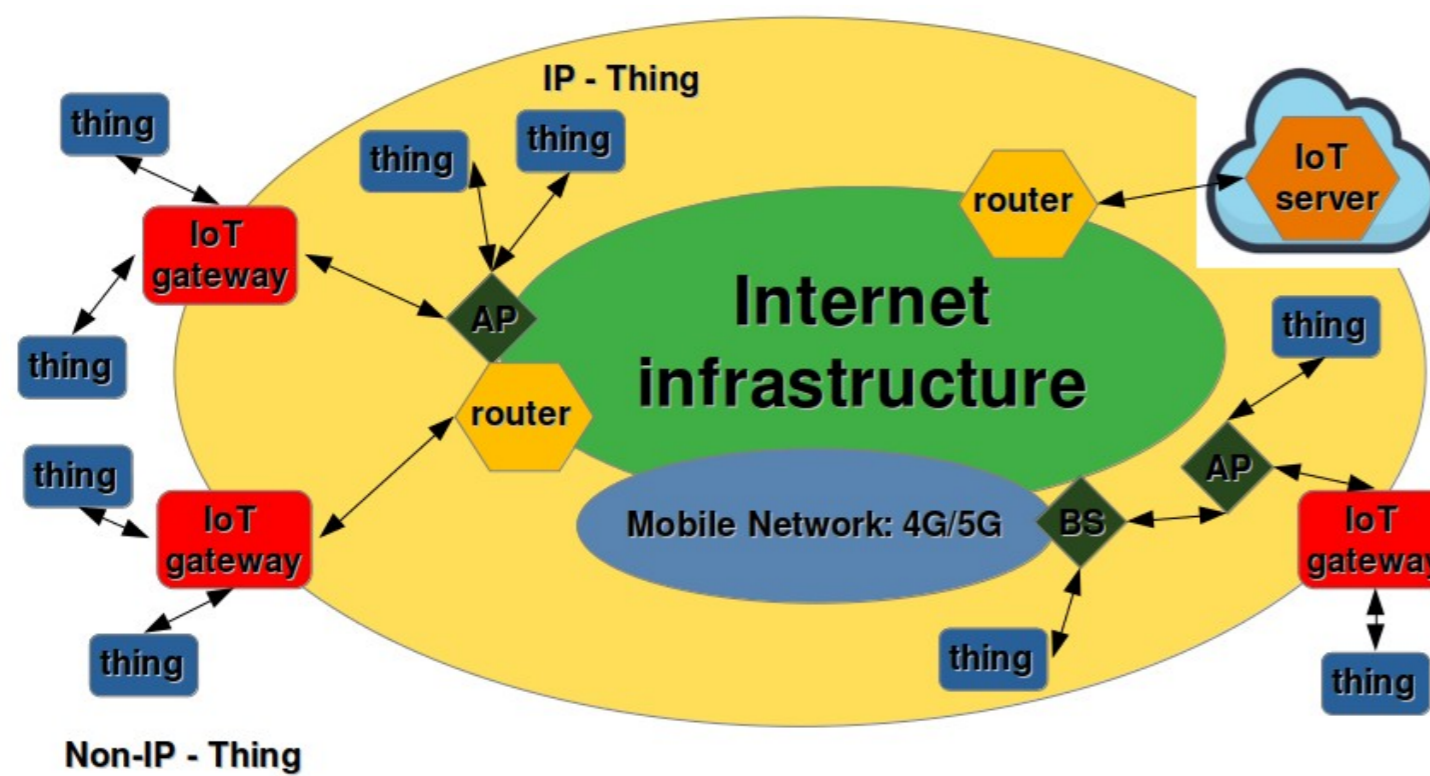
Introduction

The following study presents a complete IoT platform operating at two communication levels – **short distance** (WiFi) and **long distance** (LoRa). At both levels the terminals (**Direct Terminals - DT** and **Remote Terminals - RT**) may operate with different kinds of sensors over a **Very Low Power** consumption range. To build a two-level communication IoT architecture we transform the **Direct Terminals** into LoRa-WiFi Gateways.

This kind of IoT architecture operates with the well-adapted **LoRa-TS/MQTT** protocol that provides a natural means to associate the **Remote Terminals** and the **Applications** to the services provided. The **Applications** running on the Terminals are simply identified by ThingSpeak **channel numbers**. The Remote Terminals and the Gateways use **Soft-AES** and **Hard-AES** to protect the transmitted payloads.

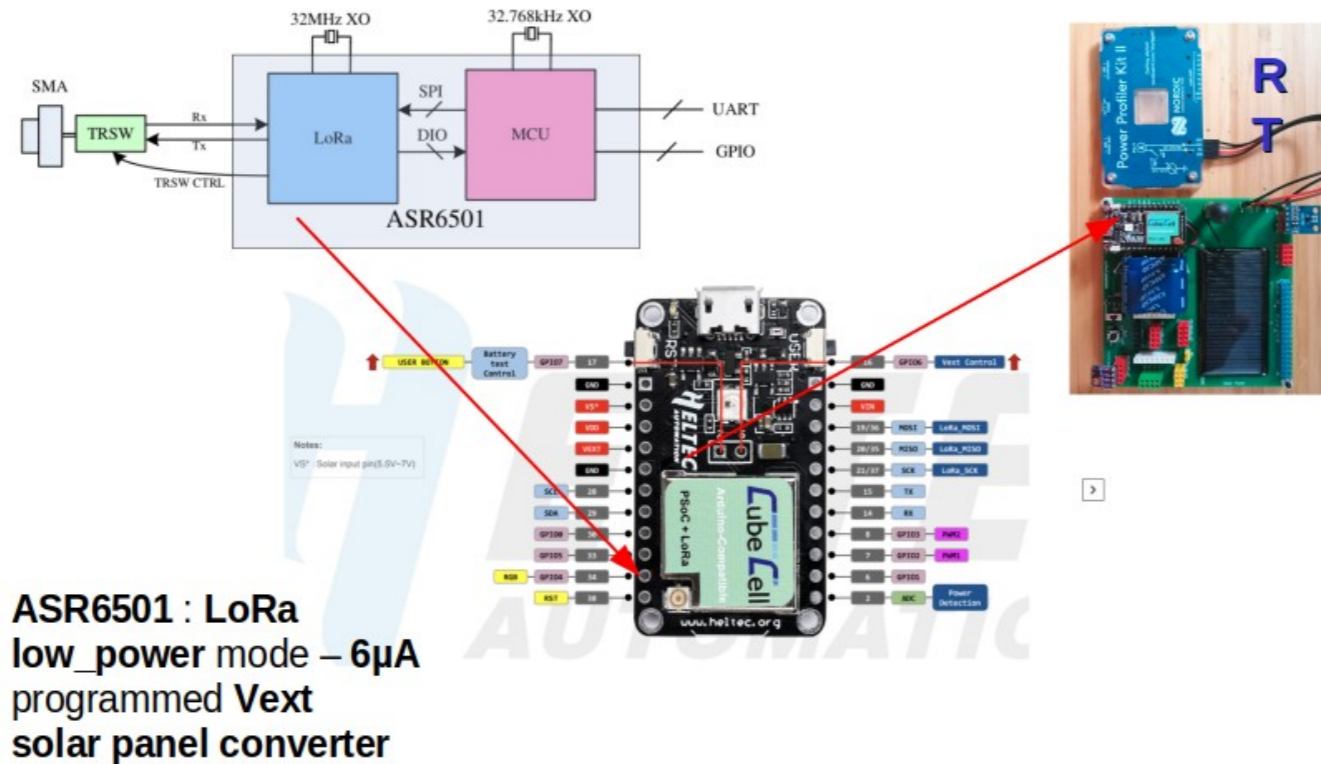
The study is based on the distinction between the **high_power** and the **low_power stages** and **phases**.

The following picture illustrates the realm of Things including Internet infrastructure, direct Internet connections and **IP-Things** (Direct Terminals), remote long range connections with IoT Gateways and **Non-IP Things** (Remote Terminals), and IoT Servers.

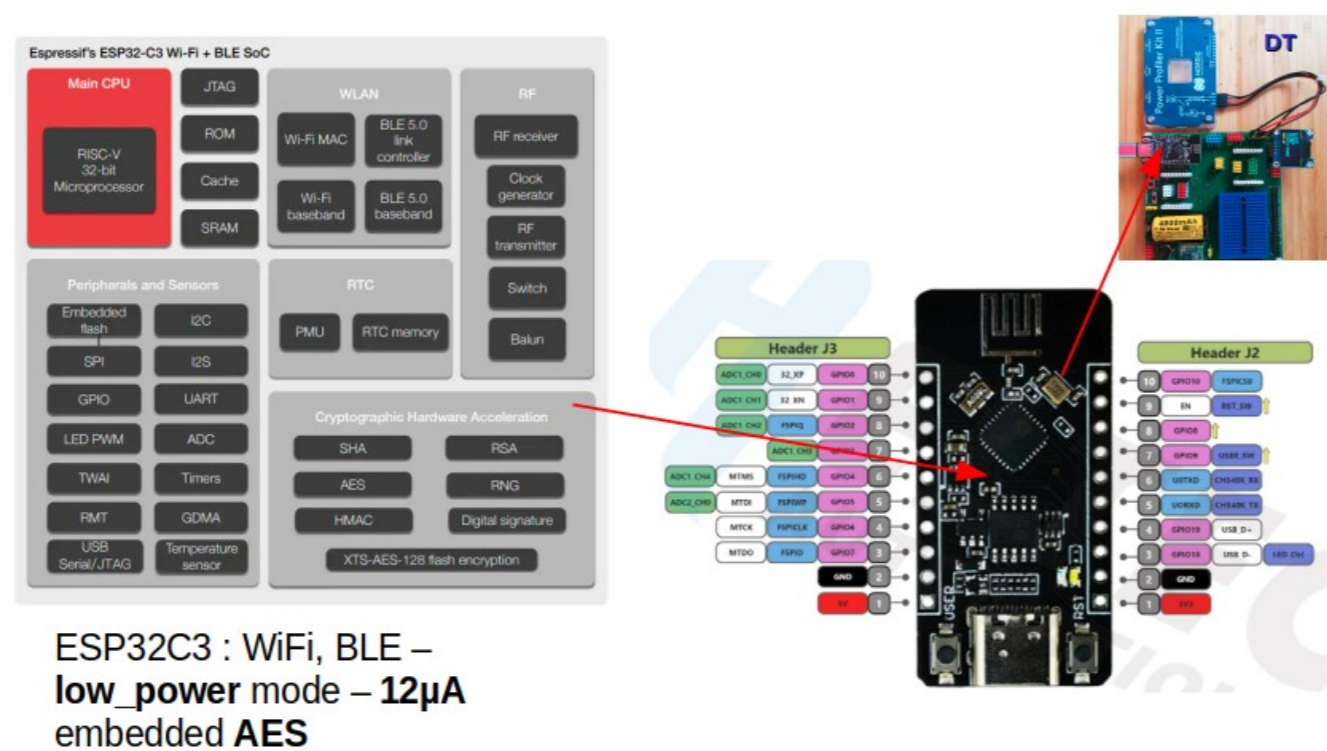


Hardware

Direct Terminals and **Gateways** are based on ESP32C3 SoC integrated in a Heltech MCU board and an IoT DevKit. This board requires only **12µA** at **low_power** stage. It features WiFi and Hard-AES blocks to function as an IoT Gateway

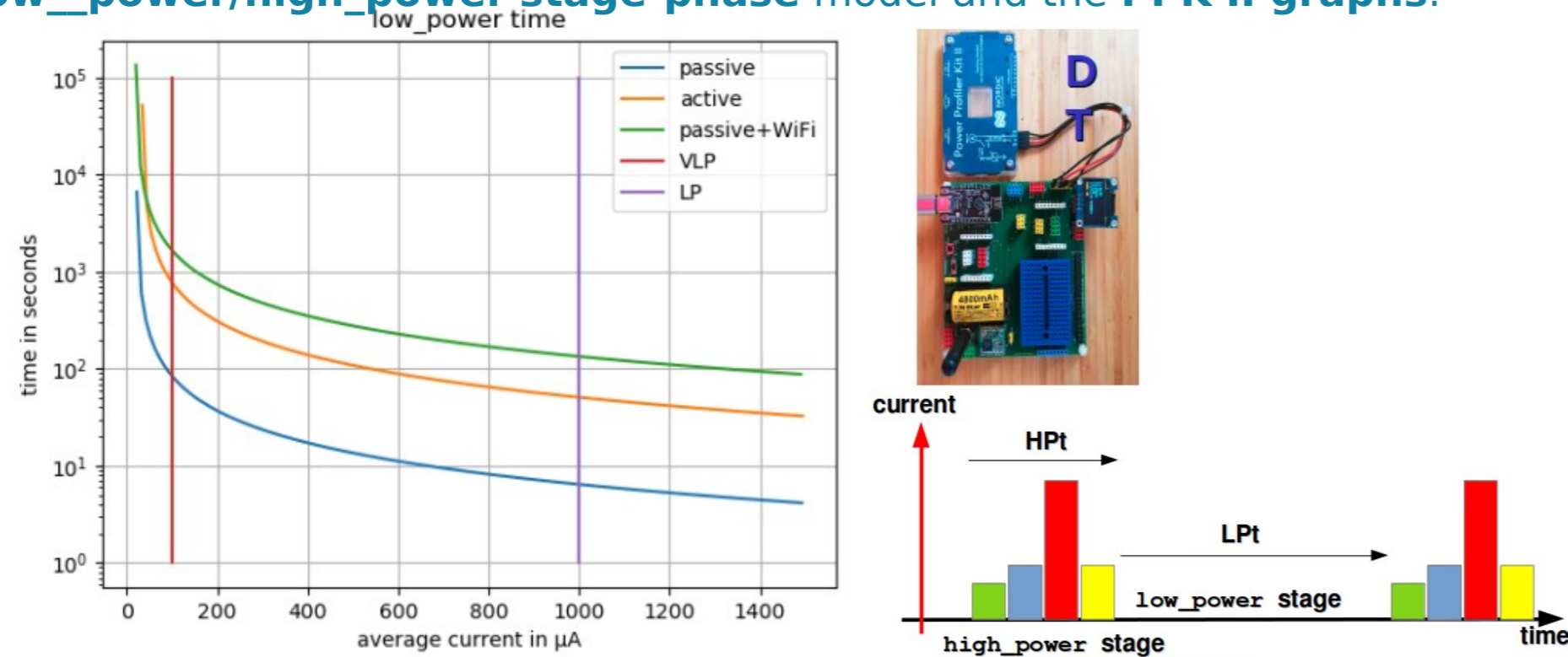


Remote Terminals are built from CubeCell modules (ARM+SX1262). This SoM needs only **6µA** at **low_power** stage. It includes battery, solar panel interfaces and provides power management via Vext and battery voltage test.



Methodology

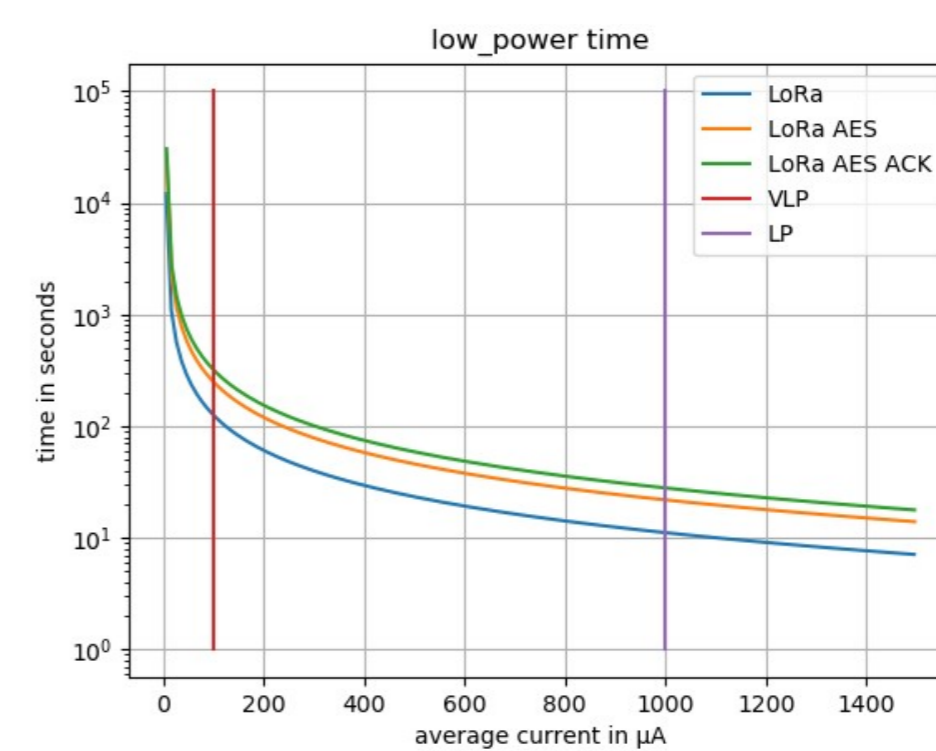
Our methodology is based on **the design/development and the analysis** of the operational aspects related to power consumption. We have selected and adapted the most complete and energetically efficient components. The analysis is done using **low_power/high_power stage-phase** model and the **PPK II graphs**.



(1) sensing passive sensor TSL5261, (2) using PIR sensor SR602 in active state, (3) sensing (BMP680) and sending via WiFi to ThingSpeak

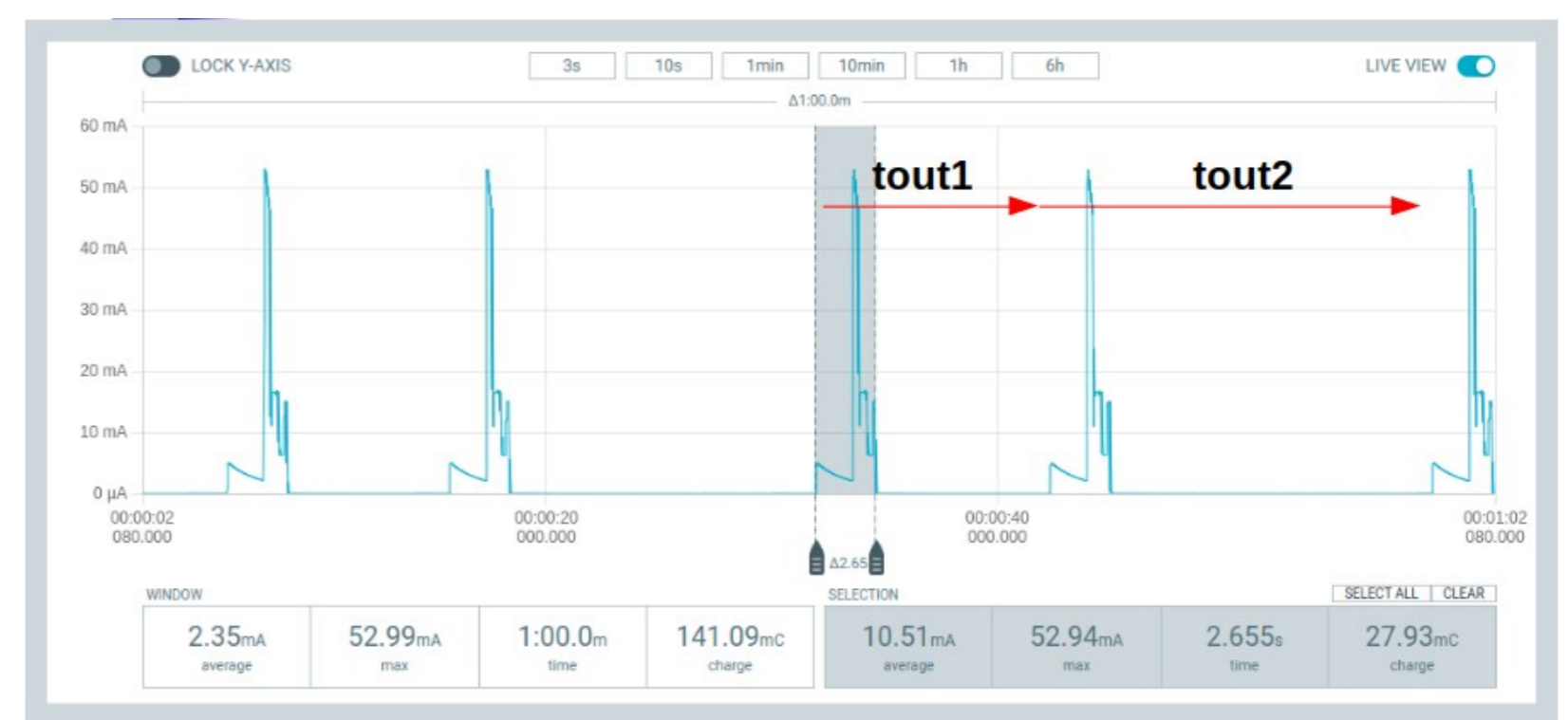
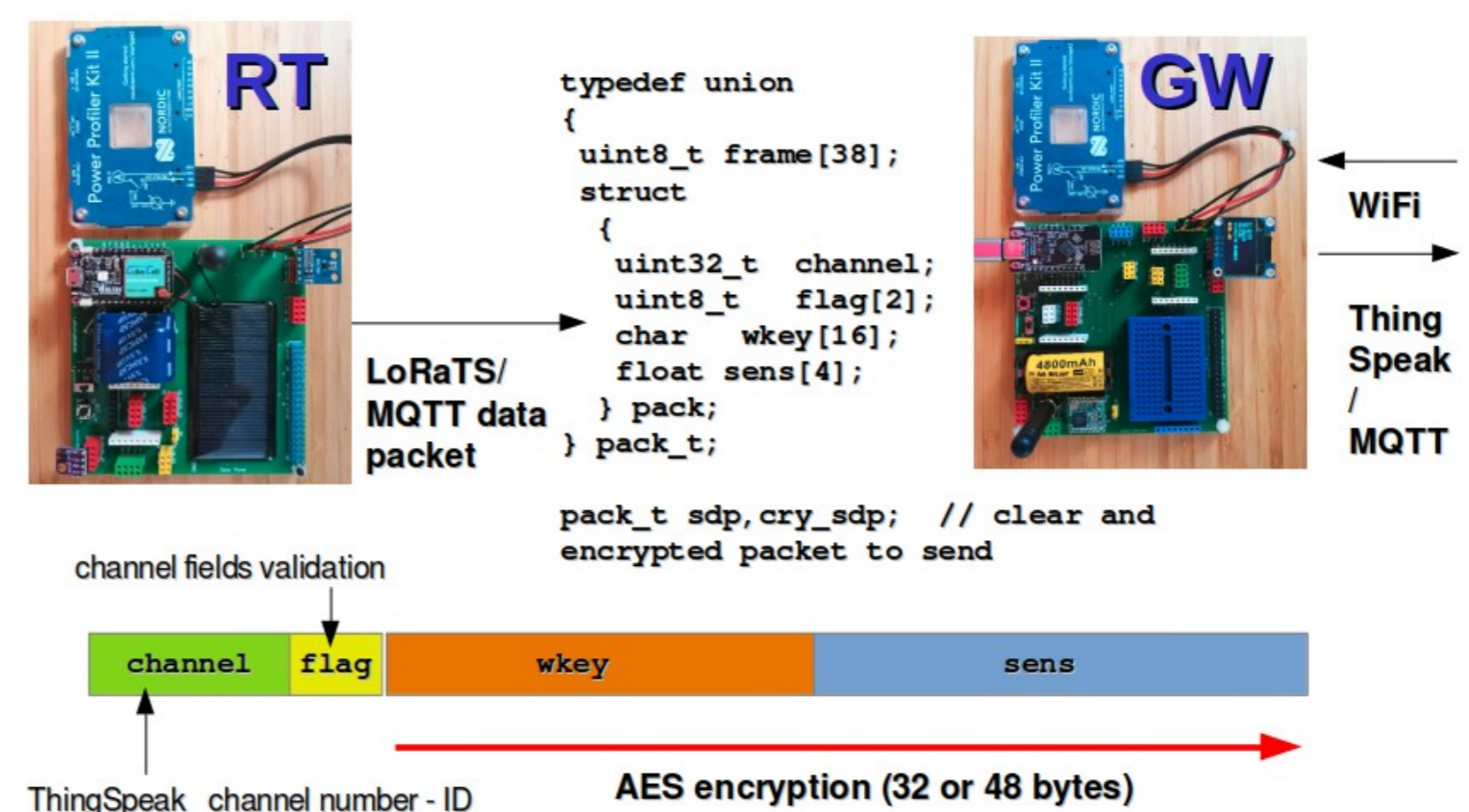
Results

The following PPK II graphs show the selected example of Remote Terminal - Application and its **low_power/high_power** operational stages/phases.



low_power stage time for 3 types of LoRa communication (protocol); simple, with AES, with AES and ACK (time-out). Data from SHT31(T/H), BH170(L)

The following figures show the elements of a complete IoT architecture with the Remote Terminal, the Gateway and the LoRa-TS/MQTT protocol.



Sending/receiving encrypted (AES) LoRa packets (data, ACK) with SHT31 and BH1750 data and time-out values (gateway controlled).

Final remarks and Acknowledgments

At first, the complexity of IoT Architectures is overwhelming. However, a long term development and analysis allows us to extract some essential aspects and components.

From the hardware point of view, ARM-Cortex-MX and RISC-V (RV32) combined with WiFi and LoRa modems are essential. These CPUs completed with hardware accelerators (AES) allow us to build energy efficient and secure IoT architectures including Very Low Power IoT Architectures.

From the software point of view, simple open source IoT brokers/servers MQTT and ThingSpeak provide essential capacities for IoT applications.

We would like to thank our colleagues and MSc/PhD students for their fruitful feedback concerning numerous courses and tens/hundreds of projects based on our IoT platforms.