SENSE IoT Platform for Environmental Research

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Introduction

SENSE is an end-to-end cellular IoT sensing platform designed for field deployments. It includes custom hardware, embedded firmware, and a web-based control system. SENSE Core devices collect environmental data, respond to remote commands, upload data, and store data locally.

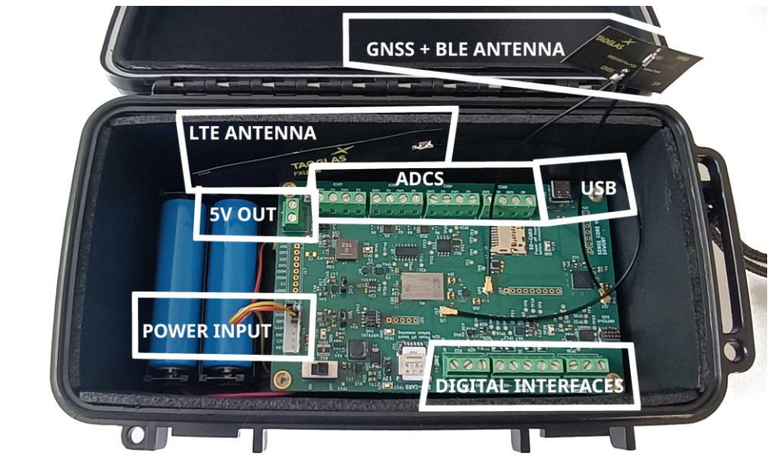

Figure 1: Overview of SENSE Core hardware.

System Overview

SENSE is a modular IoT platform designed for environmental monitoring and remote control. It consists of three core components:

Hardware:
- Custom PCB featuring a dual-MCU architecture:
- nRF9161 for cellular connectivity and control tasks
- nRF5340 for interface management (USB, SDI-12)
- Easily extensible with external sensors

Firmware:
- Written using Zephyr RTOS (Nordic Connect SDK)
- Compile time configurable via Kconfig
- Asynchronous architecture for efficient task handling
- Supports unit tests and hardware-in-the-loop (HIL) testing

Web Platform:
- Python-based application with multi-process architecture
- Asynchronous REST API built with FastAPI
- Swappable database backend for storing device data
- Efficient CoAP messaging using CBOR-encoded payloads

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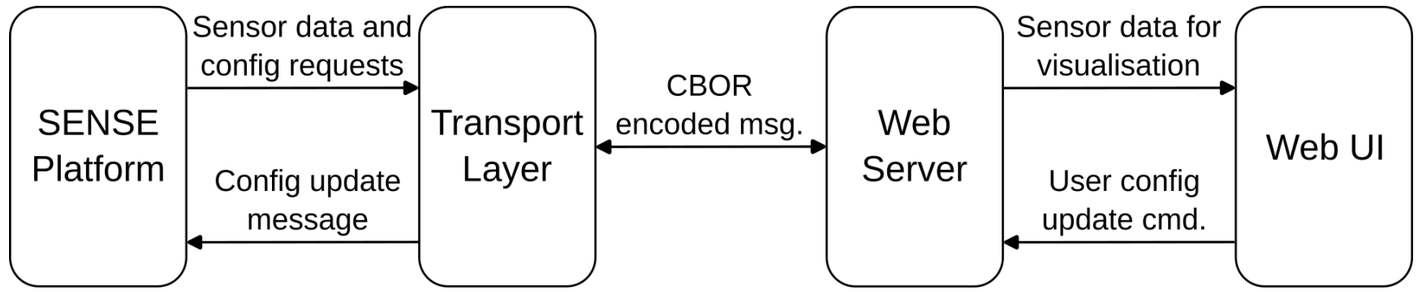

Figure 3: Overview of data flow for SENSE IoT Platform

Web Platform and Remote Control

Devices communicate with a remote server via CoAP. These requests are processed and exposed through an HTTP server for visualisation. The web interface allows users to view device metadata and sensor data, issue remote commands (e.g., change polling rate, toggle power), and manage command queues.

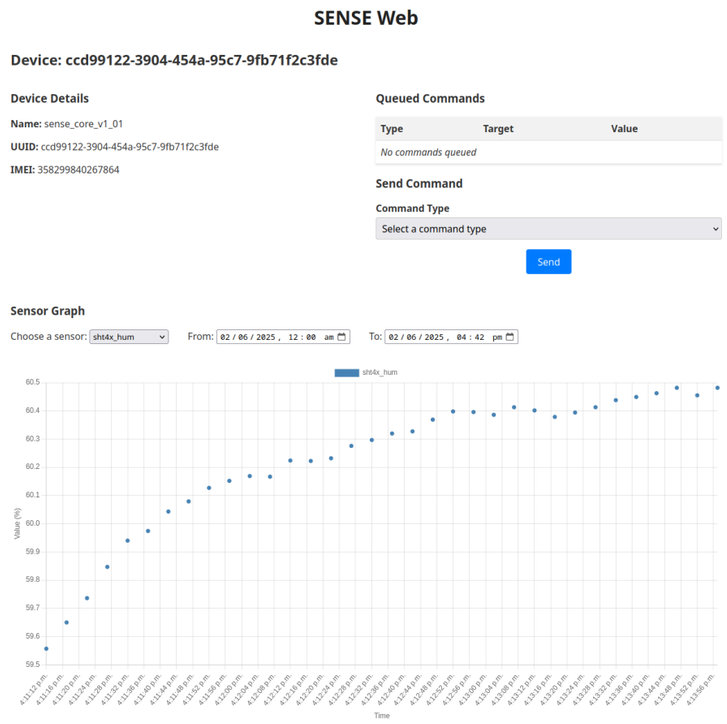

Figure 3: SENSE Web platform demo Web UI showing device detail device and command panel

Acknowledgements

Additional guidance and support provided by Brendon Duncan.

SD Card Logging

Robust Reliable Storage

The system logs sensor data to an SD card in CSV format for offline access and long-term retention. A double-buffered write mechanism ensures data integrity, with power enabled only during writes to minimize risk of corruption in case of failure.

SDI-12 Command Interface

Interactive SDI-12 Shell

The system supports SDI-12 sensors via a custom level-shifting circuit. Users can send SDI-12 commands interactively using a USB shell interface. Responses are printed live, allowing manual testing and diagnostics.

Conclusion

The system demonstrates robust core functionality, with reliable device communication, modular architecture, and an efficient web backend with remote control functionality.

Key areas for future improvement include optimising power consumption for long-term deployments and enhancing error recovery mechanisms for greater resilience. To support field-ready operation, a secondary power management PCB should be designed—enabling features like rechargeable batteries and solar charging.

Overall, the project establishes a strong foundation for a scalable, field-ready sensing platform.