Analysis, Improvement, and Development of New Firmware for the Smart Citizen Kit Ambient Board

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Introduction

What is a smart citizen?

A *smart citizen* is a person living in city who has some **influence** in

- management and organization,
- technology,
- governance,
- policy context,
- people and communities,
- economy,
- built infrastructure, and
- natural environment.

How do they achieve it?

- They **acquire** information (for example, environmental data using sensors),
- **share** it publicly, and
- use it to get **governments** take improvement **actions**.

Introduction

Current projects There exist several projects **currently active** for the development of Smart Cities, from both the public and private initiative. For example:

- Amsterdam Smart City (`http://amsterdamsmartcity.com/project`),
- Open Cities Project (UE project, `http://opencities.net/content/project`),
- Smart Santander (`http://www.smartsantander.eu/`),
- MiNT Platform by Ayuntamiento de Madrid,
- BCN Smart City (`http://smartcity.bcn.cat/`),
- and many other!

Introduction

Context of the UOC project

Objective of this UOC project: **contribute to the development of the SmartCitizen Project**.

→ What is it?

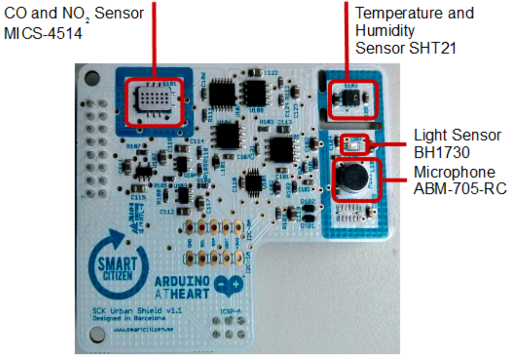
- A Smart City project (`http://www.smartcitizen.me/`).
- It was started by both the Fab Lab Barcelona (`fablabbcn.org/`) and the Institut de Arquitectura Avançada de Catalunya (`www.iaac.net`)

- They build **autonomous Arduino-compatible** boards which **collect environmental data**.
- The collected data is **sent** to a **centralized platform** to make it **public**.

Introduction

The SmartCitizen initiative produces boards (SCK) with the following **ambient sensors**:

- noise
- temperature
- humidity
- CO and NO_2 gas concentration
- lighting
- number of WiFi networks around



Global objectives

Objectives of this UOC project. This UOC project has **two parts**:

PART I: improve current SCK firmware

- **Analyze** the current firmware and learn how it works.
- **Document** both the firmware and hardware.
- **Correct** any **bugs** found.
- **Improve** the overall **quality** of the current firmware.

PART II: create the firmware for the RTX4100

- The RTX4100 is a **low-power WiFi** module.
- It will be used in new versions of the SCK.
- A previous code does not exist. It had to be written **from scratch**.

Cross tasks

The are several **cross tasks** which span both parts of the project and were performed **continuously**:

- **Continuous refactoring**.
- **Communication** the **SmartCitizen team** (Guillem Camprodon and Alex Posada, mainly).
- Periodic and frequent **unit testing**; Follow an approach close to **Continuous Integration**.
- **Writing documentation**. In particular, **automated** documentation using *Doxygen*.
- Analyze the current firmware and learn how it works.
- **Document** both the firmware and hardware.
- **Correct** any **bugs**.
- Improve the overall **quality** of the current firmware.

Part I

Part I

Analysis, documentation, and improvement of the current SDK firmware

Part I: current situation

What was the situation when I started the project?

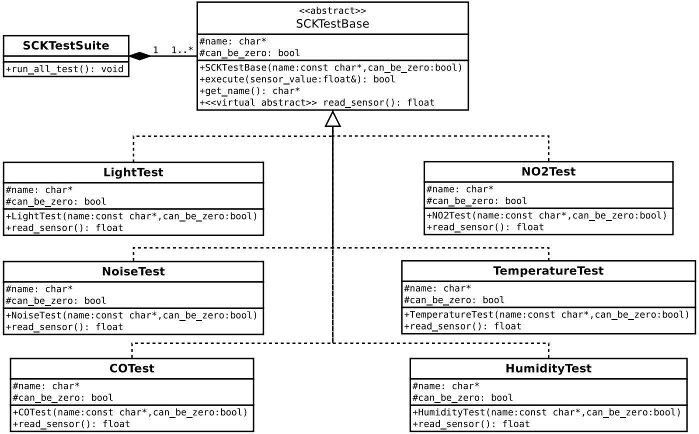
- **Hardware** design totally **finished**. In production.
- Firmware overall working and **in production stage**.
- Firmware C++ project **publicly available** at `gitHub`.
- **Lack of unit testing** which would ensure quality of further improvements.
- **Lack** of any Built-In Self Test **(BIST)**.
- **Lack** of **reference documentation**, with the exception of some descriptions of the hardware in the website.
- **Lack of automated documentation** generated from code markup (with `Doxygen`, for example).
- Some **bugs** found in the production firmware.
- Identified many parts of the **code** which **might be improved**.

Part I: engineering tasks performed

Engineering tasks performed:

- Followed a **development methodology** close to **Continuous Integration**.
- Created **proper** and **complete documentation** for all the project (UOC project deliverable).
- Created a **BIST** mode which executes **automatically** a series of tests which determine if the hardware/firmware is working correctly.
- The **BIST mode** is designed as a **unit test**, and can be **extended** with more tests.
- Used the `cppcheck` **tool** to **automatically** find and correct problematic parts of the code.
- Created functions to **prevent duplicated code**, specially for I2C communication.
- **Minimized the memory usage** by using static objects instead of duplicated instances.
- **Removed** unused (**dead**) code.

Part I: BIST UML class diagram



UML class diagram of the unit test design used in the BIST

Part I: conclusions

Conclusions of the first part of the project:

- The gas sensors in the SCK need to be **recalibrated** after some months. Since regular users can not do it by themselves, it is better to **avoid** these kind of sensors in next versions of the SCK.
- **Complete documentation** for the project (hardware and firmware) was written.
- **Automated documentation** was added in the source code (with `Doxygen`).
- A new **BIST** mode was added, which is designed as a unit test that can be **extended** with more test cases.
- All found **bugs** were **corrected**.
- **Several improvements** were performed: memory saving, move variables to private or lower scope, create functions to avoid duplicated code, etc.
- The RN131 WiFi module consumes **too much energy**. It must be **changed** by a more efficient module. This is discussed in Part II.
- Therefore, **all the objectives** of the first part of the project have been **met**.

Part II

Part II

Design and create from scratch the firmware of the new RTX4100 WiFi module

Part II: motivation

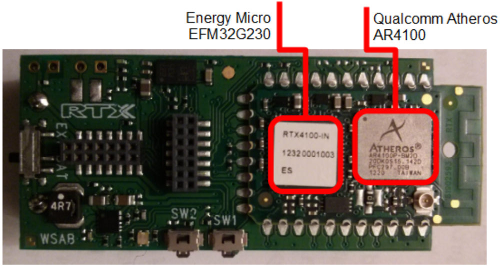
Motivation of the second part of the project: writing a complete firmware for the RTX4100.

- The current RN131 WiFi module in the current version of the SCK v1.1 is the component which **consumes the most power**. It must be **replaced** by a more efficient alternative.
- The proposed **alternative** is the **RTX4100**, which combines a **EFM32G230** microcontroller with the Atheros **AR4100** WiFi chip.
- RTX4100 works with its own **RTOS operating system** and software framework (**CoLa** applications).
- A **firmware** to manage the RTX4100 hardware is needed.
- Since the RTX4100 has its own microcontroller, it can be used to **manage communication** at the OSI transport level (TCP connections) and **free** the main SCK microcontroller from these duties.

Part II: requirements

Requirements of the firmware developed for the RTX4100:

- It should work in a way which ensures **minimum energy consumption**.
- It must provide an **API** to control **all energy parameters** and to adjust them when needed (i.e: signal strength, among others).
- The API must provide functions to send/receive data at the OSI transport level (**TCP connections**).
- The communication with the upper layer must use binary (**non-verbose**) commands through the **SPI protocol**.



The low-power RTX4100 WiFi module

Part II: characteristics of the developed firmware

The firmware was designed such a way it meets all the stated objectives, taking special care of the energy consumption constraints.

- The developed firmware architecture is **event**-driven. Therefore, the CPU is only active when it needs to process an event and idle otherwise. This ensures **minimal energy consumption**.
- The system is **modular** and most of the functions are implemented as **RTOS protothreads**. No polling loops.
- To help debugging, a **debug mode** through a **serial terminal** is available.
- **SPI communication** is used in production mode.
- A **unit test** function is available as a debug terminal **command**.
- Several **energy control functions** available to the upper layer.
- **TCP communication** functions available to the upper layer through the API.

Part II: conclusions

Conclusions of the second part of the project:

- The RTX4100 hardware and its developed firmware have been **documented properly** at the UOC project deliverable.
- The developed **firmware is finished** and **publicly** available at `https://github.com/mcolom/SmartCitizenRTX4100` under the **GPL** license.
- Automated `Doxygen` **documentation available**.

- **All the objectives for the RTX4100 second part of the project have been met in time**.

Thank you for your attention