Work in Progress: Pocket Labs in IoT Education

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Abstract. This work in progress describes the ongoing initiative at CUAS to use Internet of Things (IoT) technologies for educational purposes. First, it describes the relevance of Internet of Things technologies in education, next it focuses on different hardware platforms used by CUAS. The main part describes the implementation of one specific example developed by students, the MIA-project. Finally, it gives an outlook on how future student projects will benefit from the lessons learned.

Keywords: Internet of Things (IoT) · Bachelor degree program
Raspberry Pi · Arduino · Teensy · Blend Micro
Project-based learning · Pocket Labs

1 Introduction

Internet of Things (IoT) technologies tend to be one possible future of engineering in general. In the last 2–3 years in Higher Education the trend to a Maker University is one of the mainstream trends. For engineering study programmes, which traditionally had both, a theoretical and a lab part, this means at first instance the close (thematically and from a timeline point of view) connection of the experimental and theoretical part of teaching.

IoT technologies incorporate many different aspects of technical systems. They usually consist of a microprocessor/microcontroller which can be used stand alone or with an operating system, e.g. Linux. The application software can be programmed using the traditional C/C++ approach or by applying emerging programming languages like Python and Processing. IoT systems are equipped with interfaces to the outside world, both analogue and digital. Sensors, attached to these interfaces can measure a wide range of physical entities with astonishing precision and sampling rate. Last, but not least, IoT systems are equipped with communication means to interact with other IoT devices. Bluetooth, Zigbee, WiFi, and LoRaWAN are some of the possible choices.

During the last years, CUAS has successfully introduced various kinds of IoT systems and technologies into a growing group of bachelor degree courses (e.g. Real-Time Systems, Bus systems and Protocols, Algorithms and Datastructures). This work in progress description provides an overview about different kinds of IoT systems currently used at CUAS. It also explains one specific IoT student-project in detail.

2   IoT at CUAS

At CUAS, we are using different IoT architectures and systems. Since different applications demand different levels of complexity, speed, composability, and interoperability, the one fits all solution cannot and will not be applied.

Arduino is one major IoT device used by CUAS. Due to its ease of use and high flexibility, it is the ideal choice for beginners as well as for experienced students. The integrated development environment (IDE) with its built-in Processing programming language and the high number of extension boards (shields) with corresponding software libraries provide a limitless playground for various kinds of projects.

We use Arduino as a base platform which means that depending upon the current requirements of our applications, students need to choose a clone-version. Two clones we are using are the Blend micro and the Teensy board.

The Blend Micro board (see Fig. 1) is at its heart an Arduino blended with a Bluetooth Low Energy (BLE) interface into a single board. It is targeted for makers to develop low power Internet-Of-Things (IoT) projects quickly and easily. The micro-controller unit (MCU) is Atmel ATmega32U4 and the BLE chip is a Nordic nRF8001. Blend Micro runs as BLE peripheral role only, it allows BLE central role devices to establish connections with it [1].

The Teensy 3.2 USB development board (see Fig. 2) is a complete USB-based microcontroller development system in a very small footprint capable of implementing many different types of projects. The Teensy is a breadboard-friendly development board. Each Teensy 3.2 comes pre-flashed with a bootloader and can be configured directly using USB. It can be programmed in C or by using Arduino sketches for Teensy. The processor on the Teensy also has full access to the USB and can emulate any kind of USB device [2].
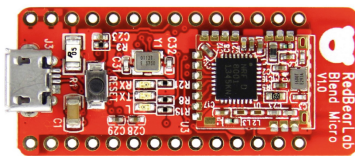

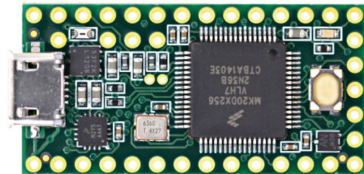**Fig. 1.** Blend Micro board.

Fig. 2. Teensy 3.2 board.

The Raspberry Pi 3 Model B (see Fig. 3) has a 1.2 GHz 64-bit quad-core ARMv8 CPU, 802.11n Wireless LAN, Bluetooth 4.1, Bluetooth Low Energy (BLE). It is used in combination with extension-boards, breadboards, cameras, sensor/actor kits, etc. The Raspberry Pi is setup with the appropriate OS (Raspbian, Windows 10 IoT, Ubuntu). Programming takes place using Python, C or C++ [3].
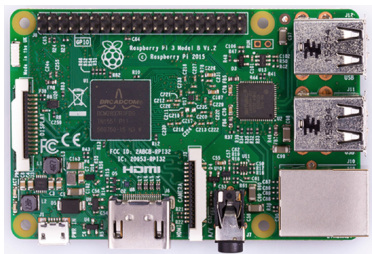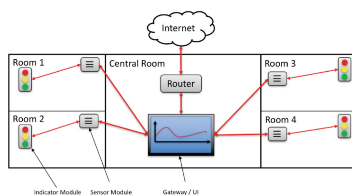
Fig. 3. Raspberry Pi 3.

Fig. 4. MIA Overview.

3 Managed Indoor Air (MIA) Student Project

3.1 General Overview

The goal of the MIA student project was to develop an air measurement system using IoT technologies. The three main aspects of this project were: the choice and configuration of the hardware, software development for different target platforms, and the configuration of the appropriate communication interfaces.

The whole application was split into three IoT modules (see Fig. 4):

– the Sensor Module, capable of measuring the CO_2 concentration of the air, the air temperature and the humidity,
– the Indicator Module, providing a simple and intuitive way to show humans when to open a window to ventilate, and
– the Gateway Module, which is used to graphically represent the acquired data from the sensor module and it also acts as the gateway into the internet and portal for a cloud-based storage system.

To interconnect the three different modules, a communication architecture was developed (see Fig. 5). The final choice was to use BLE to connect the Sensor module to both, the Indicator module and the Gateway module and to use WiFi to connect the Gateway module via a router to the internet.

3.2 Sensor Module

The purpose of the Sensor module (see Fig. 6) is to measure the CO_2 concentration of the air, the air temperature and the humidity and to transmit this data using BLE to the Gateway Module.

The Sensor module consists of the following components:

– Teensy 3.2 (Arduino compatible IoT device),
– Adafruit BME280 (temperature and humidity sensor),
– Telaire T6615 (CO_2 Sensor), and
– BLE2 Click (BLE Module).

The CO_2 Sensor and the BLE Module are connected to the Teensy using UART, the BME280 uses I2C as its interconnect (see Fig. 7).
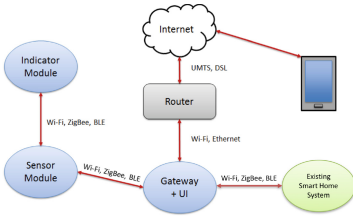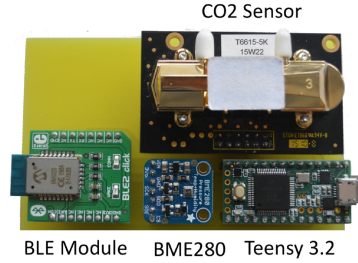
Fig. 5. MIA Communications Overview.

Fig. 6. Sensor module.

3.3 Indicator Module

The purpose of the Indicator module (see Fig. 8) is to provide a simple and intuitive way to show humans when to open a window to ventilate by using a RGB LED. If the LED is turned off, the air quality is good. If the LED turns on to yellow, the air quality is medium, and if the air quality is bad, the LED turns to red. After the air quality has reached a good level again, the LED turns off.
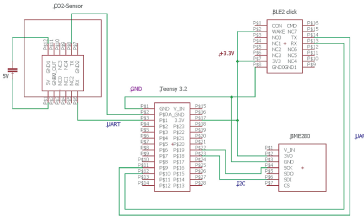

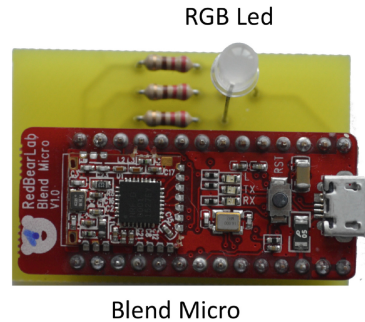Fig. 7. Sensor module internal interconnects.

Fig. 8. Indicator module.

The Indicator module consists of the following components:

– Blend Micro Board,
– RGB Led, and
– BLE module (integrated).

3.4 Gateway Module

The purpose of the Gateway module (see Fig. 9) is to graphically represent the acquired data from the sensor module and to act as the gateway into the internet and portal for a cloud-based storage system.

The Gateway module consists of the following hardware components:

– Raspberry Pi 3,
– Raspberry Pi 7" LCD Touchscreen,
– BLE Module (integrated), and
– WiFi 802.11n (integrated).

The Raspberry Pi 3 is using Raspbian a Debian Linux clone as operating system. The following software components are also installed on this IoT-device (see Fig. 10):

– Apache 2.4.10 Webserver,
– SQLite 3,
– Python 2.7,
– PHP/HTML,
– Google Charts API, and
– Chromium.
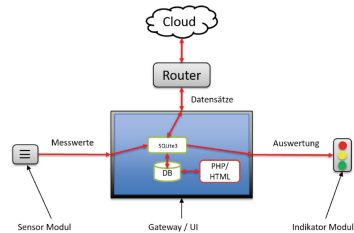

Fig. 9. Gateway module.

Fig. 10. Software components.

SQLite is managing the database (DB), Apache Webserver acts as the external interface to the DB and PHP/HTML are the transport protocols used. The Google Charts API is used to draw diagrams and Python is used as the programming language.

3.5 Overall Results

The IoT student project MIA was very successful. Three students have been working over a period of seven months and completed the project not just in time but also three weeks earlier. The budget was not overspent and two independent MIA systems have been build. They are being used at CUAS and they certainly are references for future projects in this field.
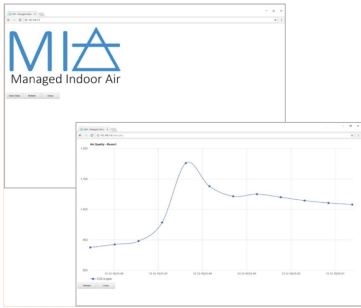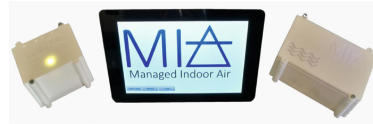
Fig. 11. GUI Measurement results.

Fig. 12. Final MIA system.

In Fig. 11, the graphical representation of the measurement results on the Gateway module can be seen. The same representation can be accessed via the Internet using a browser or a Smartphone.

The project group also designed and constructed housings for the individual modules, which can be seen in Fig. 12. The in-house 3D-printer of CUAS has been used.

4   Outlook

Due to the large and obvious relevance of IoT technologies, students are very much interested in similar and future IoT projects. Not all projects require a complete hardware and software design from scratch the challenge in the future will be to identify candidates for the IoT approach and the others intended for custom embedded systems design.

As the developed modules can be used for mobile measurements as well as for laboratory exercises, they satisfy the definition of Pocket Labs [4], being portable electronic devices for mobile measurements.

References

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