Demo: Off-the-Shelf Bi-Directional Visible Light Communication Module for IoT Devices and Smartphones

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Abstract

In this demonstration, we propose a line of sight bi-directional communication system between an ordinary LED and an off-the-shelf smartphone. We designed a cheap multi sensors device as a proof of concept of a near communication module for the Internet of Things.

To illustrate a typical use case, we have programmed the micro-controller to broadcast the sensors values and the battery level using the LED. The same LED, reverse-biased, is also used as receiver to get some data, without the need of additional hardware modifications.

Also, thanks to the the serial bus, the board can be connected to an embedded device, such as a Raspberry Pi, to serve as a VLC module, offering numerous IoT applications.

On the other side, a user with his smartphone and our Android application can then retrieve the transmitted information, or send a configuration command thanks to the flashlight, letting him change the color of the RGB LED.

1 Introduction

With the rise of the Internet of Things (IoT), consumer electronics products, which yesterday were single function, tend to be smarter and connected to the user, through his smartphone. However, providing wireless connectivity with Bluetooth Low Energy (BLE) or WiFi means adding an extra radio chip, increasing the object size and price.

This kind of hardware modification is not without impact for the manufacturers: even if the radio chip cost is negligible for a single unit, it may become huge when millions of products are sold. Also, the health impact of radio waves is not yet fully understood.

However, many of these products already have a micro-controller unit (MCU) and light-emitting diodes (LED), which are the only requirement to enable visible light communication [5]. While photodiodes are commonly used as a light receiver, the transmitting LED reverse-biased can be used as receiver [3], enabling half-duplex communication. To further reduce the cost of the system, an off-the-shelf smartphone can receive information through visible light thanks to its camera [1], while its flashlight can be controlled to send data [4], as shown in figure 1.

This demonstration aims to illustrate such a scenario, which targets short-range (tens of centimeters) and low throughput (tens to hundreds of bits per second) communications for the IoT.

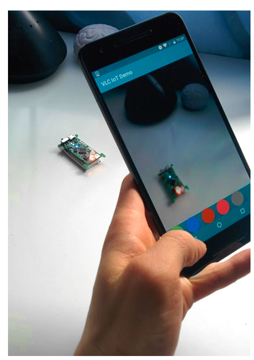

Figure 1. Aiming the VLC board with his smartphone, the user is getting the board battery level. It can change the small RGB LED color by pressing the corresponding button in the app.

2 Use cases

Even if the throughput and the range of this kind of communication are very limited [2], potential applications exist. VLC can then be a cheap alternative to traditional radio communication, when the application reads only small payloads coming from a sensor, such as a battery level or a temperature value, or occasionally configure a device. In fact, any electronic product for which the wireless function is secondary and rarely used might be a candidate for our solution.

In this regards, we propose a comprehensive VLC transmission system using just a low-cost, low-power colored LED that is most probably already part of the design of candidate devices. On the user side, our application runs on an unmodified smartphone. The additional costs to make a traditional device part of the IoT are therefore minimal.

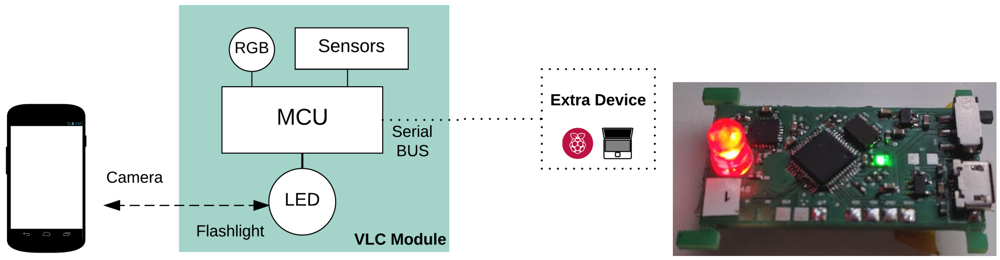

Figure 2. On the left, the demonstration block diagram. On the right, our demo board

3 System description

3.1 Smart VLC device

We designed a 40x20mm printed circuit board (PCB) shown in Figure 2 that supports a red 5mm LED, a micro controller unit (MCU), a 6-axis and temperature sensor. Also, we place a surface mount device (SMD) RGB LED whose color can be easily changed.

The MCU is a low cost and low power Cortex M0+ STM32L051. We configured the clock speed at just 8MHz using the high speed external crystal oscillator. The board is powered by a 3.7V polymer lithium battery, rechargeable through USB.

The firmware we developed works in the following way. After enabling all needed peripherals, the MCU is placed in low-power mode, waiting for the beginning of a transmission, coming from the smartphone flashlight.This is achieved by periodically waking-up the MCU, sensing the reverse-biased LED, and taking the decision to go back to the low-power mode or stay active to handle subsequent transmissions.

3.2 User smartphone

On the user side, we use a Huawei Nexus 6P smartphone running Android Nougat version number 7. Using the Camera2 API, we configure its CMOS sensor to take advantage of the rolling shutter effect.

For this demonstration, we have developed an application that can transmit a short message to the LED using the flashlight and also receive information from the same LED as depicted in Figure 1.

A background thread processes the signal from the camera and decodes the payload. To not display on screen the dark and striped pictures produced by the rolling shutter effect, captures are made in burst mode: the first frame, taken with regular parameters, is displayed in the app, while the other one, taken with a short exposure time, is sent to the background thread.

In this way, by moving his smartphone, the user can see the ambient temperature, the board orientation or the battery level in a popup that follows the LED on the screen, in an augmented reality fashion.

On the other hand, to illustrate the smartphone to LED link, using our application, the user can change the onboard RGB LED or select the sensors values to be broadcast.

4 Demonstration scenario

This demonstration will illustrate different use cases and potential applications of our work. We set up three scenarios using the board as a standalone device, or as a module connected to a Raspberry Pi (RPI) or a laptop.

RGB LED and board configuration: using the application, the user can wake up the board, change the color of the RGB LED and select which sensor values are broadcast. Also, it can place the board in low power mode.

Sensors values broadcast: according to its configuration, the board broadcasts through VLC the selected sensor values: orientation, acceleration, temperature, battery level. The user, by aiming at the LED, can see them in real time on the screen.

VLC Raspberry Pi module: the board is connected to a RPI through its serial bus, working as an external VLC interface. On the smartphone side, the user can type a text and send it to be displayed on the RPI LCD screen.

5 Conclusions and further works

This demonstration proposes a comprehensive VLC application for the IoT by using a low-cost, low-power colored LED and an off-the-shelf smartphone. This work spotlights the VLC technology as a great opportunity for smart and connected consumer electronic products, providing device-to-device half-duplex communication.

However, some issues have to be solved. Access control and network layer protocols are still missing and have to be designed to make the transmission efficient and reliable. Also, packet addressing and larger message size should be taken into account and will be addressed in further works.

6 References

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