Demonstration Abstract: Enabling WSN Nodes to Send Data to Smartmobiles by Blinking LEDs

Jo-Ping Li
Department of Computer Science
National Tsing Hua University, Taiwan
Email: zeroping.tw@gmail.com

Shin-Yi Chang
Department of Computer Science
National Tsing Hua University, Taiwan
Email: littlesakt@gmail.com

Pai H. Chou
University of California, Irvine, USA
and National Tsing Hua University, Taiwan
Email: phchou@uci.edu

***Abstract*—Greendicator is an indicator system that enables embedded systems to output text to camera-equipped smartphones by blinking an LED. The transmitter emits modulated light pulses using an existing visible-light LED or an IR diode, laser, or light reflector. The receiver uses a camera-equipped smartphone to sense the light pulses and GPU to decode the original message. We demonstrate its use in supporting existing RF-based networks and an aid for pairing and configuration of wireless systems while occupying only a small memory footprint.**

I. Introduction

Wireless sensor networks (WSNs) applications usually demand low cost or small size, thereby forcing the hardware to be built with minimal resources and to forego features such as text displays. A smartmobile (smartphone or tablet) can serve as a convenient general-purpose display, if there is a way for the WSN node to communicate its data to the smartmobile.

Many RF protocols for WSNs exist, but smartmobiles support primarily Wi-Fi and Bluetooth but not ZigBee or other radios. Even if they do, the additional RF communication overhead may disrupt the carefully scheduled communication or tasks on the nodes. Even if RF works, one problem is that in a dense deployment, one might not be able to tell which node is which, because there is no way to "see" the wireless links, and any self-reported names by the nodes may all look very similar in the form of serial ID without descriptive names.

For all these considerations, we propose Greendicator, a practical way for using a blinking LED on any embedded system to perform optical wireless communication (OWC) [1] to a smartmobile via its built-in camera. It is meant to complement RF communication. The optical spectrum is unregulated and is free from electromagnetic interference (EMI). Virtually all embedded systems are built with at least one LED that can be readily used as transmitter with no hardware cost and very little firmware cost. If greater communication distance is desired, then one can add a conventional component such as a laser diode without modifying the rest of the system. We believe that this capability is practical for a wide range of scenarios from in-field debugging aid and diagnostics output to assisting end users with pairing a wireless device to a smartmobile in an easy-to-use, secure way.

II. System Overview

Fig. 1 shows the architecture of Greendicator. It is composed of a wireless sensor node as the encoder and a smartmobile as the decoder. Given the payload to transmit, the modulation unit on the encoder maps the payload bits into a sequence of binary optical signals to be sent to the optical emitter. We make the encoding process as simple as possible to extend the application scale. For debugging support, Greendicator provides an API for programmers to set the messages and variables to be displayed.

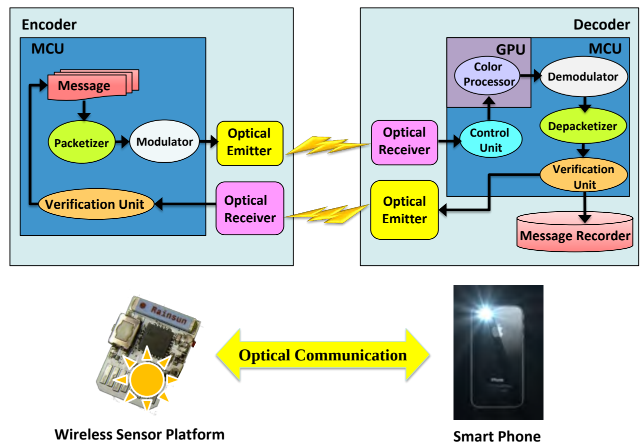


Fig. 1. System Overview.

On the decoder side, the smartmobile receives the optical pulses from the live video from the phone's camera and displays the decoded message in the Greendicator app as shown in Fig. 2. The user can choose the recognition target by pointing to its region as displayed on the screen. With the interactive interface, the user-defined target area will be processed by the GPU on the smartmobile. The smartmobile handles most of the tasks, including processing user commands, image processing, pulse demodulation, recording the messages, and displaying them.

III. Demo Hardware

The hardware we propose to demo is an ultra-compact wireless sensor platform based on the Nordic nRF24LE1 microcontroller unit (MCU) with an integrated RF transceiver in a 4×4 mm^2 QFN package. The MCU core is based on the 8051 instruction set architecture (ISA), and the nRF24LE1 has 16 Kbytes of on-chip flash for code memory and 1 Kbytes of on-chip RAM as data memory. Our purpose is to show that

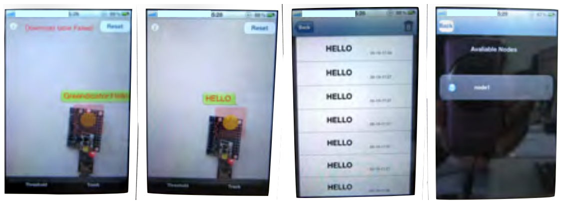


Fig. 2. The screen shot of decoding process with using iPhone 4S as decoder. The welcome message shows (the leftmost). After successful decoding (the second). The available nodes (the third). The recorded messages with timestamps (the rightmost).

(a) OP520 (b) Top (c) Bottom

Fig. 3. Photo of OP520 and MicroNode

Greendicator can be implemented on such a highly resource-constrained embedded system.

We also demonstrate Greendicator on another more wireless sensor platform based on the TI CC2540 MCU with Bluetooth 4.0 Low Energy (BLE). It has 8 KB of data SRAM and 256 KB of code flash. It is programmed to require a key code to complete the pairing process.

Besides the transmitter using the built-in LED, we also added a photo transistor, the OP520 as shown in Fig. 3(a), to receive optical signals generated by the smartmobile for the purpose of acknowledgment. A pushbutton is also available as an input device for the users. Fig. 3 show the top and bottom views of the embedded hardware.

To demonstrate the ability of Greendicator to work with other optical emitters including an IR emitter and a laser diode, we build additional add-on boards to be interfaced to the original MCU board. The first is an IR (infrared) transmitter, which is invisible to humans but is still visible to the camera, and thus may cause less annoyance than blinking lights. The second is a laser diode, which can achieve much longer transmission distance than RF while consuming significantly lower power and in a much smaller size. Fig. 4 illustrates the idea that the user can just use the same camera on the smartmobile to decode the message, regardless of the transmission medium.

IV. Demo Scenarios

The first demo scenario is to show that the smartmobile can run our decoder app to aim at the blinking light spot, whether emitted by the built-in LED, IR, or a laser spot on the wall, and display the text message. This will give the audience a feel for the basic capability of our Greendicator system.

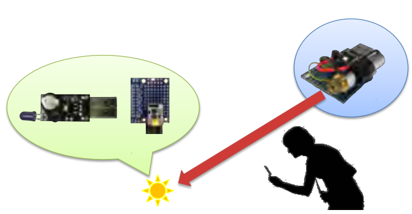
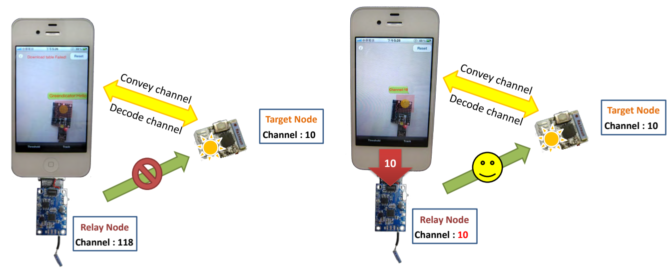


Fig. 4. Scenario of a multi-optical indicator. The module from left to right is IR transmitter, SMD LED and laser.



(a) Before configurations (b) After configurations

Fig. 5. Scenario of a channel decoder

The second demo scenario is to use Greendicator as a wireless pairing aid. The user's smartmobile is initially unpaired with a wireless node, which can be thought of as a product fresh out of the box. The node blinks its pairing key via its Greendicator LED output, and the user just needs to aim their smartmobile camera at the LED to pick up the pairing key. This enables the smartmobile to pair with the node in a one-touch, intuitive, unambiguous way. It is also secure in the sense that no one else is in direct line-of-sight from the LED and cannot "hijack" the node without the pairing key.

Fig. 5 shows another scenario with the Nordic node where the relay node cannot communicate with the target node due to the different RF channel, as shown in Fig. 5(a). By using a smartphone to decode the target node, we can retrieve the channel information. Once the channel number is known, the decoder can connect to the node over RF, whether from a computer or from a smartphone through a dongle if necessary. After the programmed node changes its channel to the same as that of the target node, they can establish the communication, as shown in Fig. 5(b).

The fourth scenario is to show how Greendicator can aid debugging in a wireless sensor node in WSNs. By using our Greendicator system, programmers can call our API to output all necessary configuration data through the LED so that the debugger can function. It is unintrusive to the existing RF channel. We also shows that it occupies a small footprint of 1932 bytes of code memory and 128 bytes of data memory in our implementation. Our API can also optimize for static messages and format strings by transmitting just the string index instead of the string content. This enables reduction of required bandwidth in string formatting and faster response time.

Acknowledgments: This work was sponsored by Ministry of Economic Affairs (Taiwan) 100-EC-17-A-04-S1-044. The author thanks all the members in Embedded Platform Lab for their support.

References

[1] K.-D. Langer and J. Grubor, "Recent developments in optical wireless communications using infrared and visible light," in *Transparent Optical Networks, 2007. ICTON '07. 9th International Conference on*, vol. 3, july 2007, pp. 146 –151.