Demo: Illuminating the Data - A New Bridge between Things and Humans

Aoi Koizuka, Yuki Hokazono, Makoto Suzuki, Hiroyuki Morikawa
Research Center for Advanced Science and Technology
The University of Tokyo
{koiao, hokachan, makoto, mori}@mlab.t.u-tokyo.ac.jp

Abstract

In the IoT era, low-cost, small-size, and intuitive data access to things is required. As such a method, LED-to-camera communication for smartphones is promising. However; there are intermittent time gaps between camera frames, which makes it unsuitable for large data transfer and thus narrows its usage to simple applications such as exchanging a few tens of bits of ID. Towards this, we propose a packet retransmission strategy which leverages the periodicity of burst packet losses. It can minimize the number of the retransmission times and prevent data losses caused by time gaps for a wide range of smartphone models. Our developed prototypes using ATtiny85 and 5 mm-LED can achieve more than 10x throughput of previous works without data losses.

Keywords

LED-to-camera communication, rolling shutter, IoT

1 Introduction

"Things" are getting information-intensive, such as electric appliances, commodities, and cars in the IoT era. As a method to acquire the stored data from these things easily, we focus on LED-to-camera communication for smartphones. Compared to prevalent radio communication technologies, this communication greatly reduces the cost and the size of things because the LED is usually embedded in them. Moreover, it also allows intuitive data transfer with the operation of simply holding a smartphone over the LED.

Recently, LED-to-camera communication methods in which multiple bits are transmitted in a frame are realized using rolling shutter effect (Fig. 1) [1–4]. However, there is always a time gap between two successive frames, which results in a burst packet loss (the red part in Fig. 1). Due to this, existing methods reduce the throughput to about 100 bps in order to ensure the reliability, which narrows its usage to simple applications such as exchanging a few tens of bits of ID.

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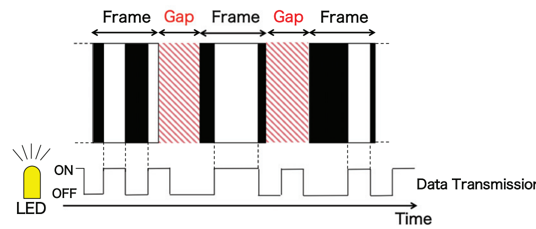

Figure 1. Due to the rolling shutter effect of the camera, the on/off status of LED is captured as white/black stripes. The width of the stripes reflects the on/off duration. The time gap between two successive frames results in a burst packet loss.

Figure 2. A LED-to-camera communication example. This communication enables easy visualization of the data stored in sensing devices.

In this work, we propose a packet retransmission strategy which can efficiently prevent data losses caused by time gaps for a wide range of smartphone models. Moreover, our evaluation shows that it can achieve 1.53 kbps throughput without data losses. The demo will allow users to visualize the several hundred sensor values stored in sensing devices using our communication method, as shown in Fig. 2.

2 Design

In this section, we describe the design which realizes reliable and high-speed LED-to-camera communication.

2.1 Packet Retransmission Strategy

In this communication method, a block consisting of N packets is transmitted repeatedly S times to deal with the burst packet losses. Since LED-to-camera communication is limited to one-way, the synchronization between a camera and a LED is not feasible. For this reason, it is necessary to capture each packet of a block in frames at least once within S times retransmission regardless of the time difference be-

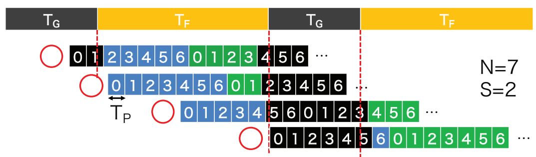

Figure 3. Packet retransmission. A camera receiver collects all of the packets in a block composed of N=7 packets in S=2 transmissions regardless of burst packet losses.

tween camera scan and packets transmission.

We found that it enables reliable communication against the burst packet losses to set N and S satisfying the Eq. 1, where T_P is a packet duration, T_F is a frame duration, and T_G is a gap duration. For example, in Fig. 3, the receiver collects all of the packets in a block composed of $N = 7$ packets in $S = 2$ transmissions regardless of the time difference between camera scan and packets transmission. Based on this formula, the throughput is maximized by minimizing S where N exists.

$$\frac{T_G + T_P}{(S-1)T_P} \leq N \leq \frac{T_F}{T_P} - 1 \qquad (1)$$

2.2 Modulation Method

In LED-to-camera communications, the clock extraction for symbol detection needs to be considered. Specifically, the rolling shutter stripe width differs from phone to phone due to the difference of a frame and gap duration. In order to facilitate the clock extraction, we adopt Pulse Width Modulation (PWM) as a modulation method. PWM realizes clock extraction only using rising up of signals and symbol detection using pulse duty ratio.

3 Implementation

We implemented a sensor node which measures temperature periodically and transmits the stored data to a smartphone.

Transmitter: The transmitter consists of an ATtiny85 as a microcomputer, a 5 mm-LED, a temperature sensor, a tact switch, and a power circuit, as shown in Fig. 4. The 5 mm-LED is covered with a silicon cap to diffuse LED light. Normally, the ATtiny85 stays in sleep mode and the LED stays off. Temperature measurement is conducted periodically (e.g., once an hour). The several hundred latest sensor values are stored in SRAM of ATtiny85. The LED starts to transmit the stored data when the tact switch is pushed. The transmitted data include the sensor values, the number of them, and the elapsed time since the latest value was measured.

Receiver: Various Android smartphones can be used as receivers by setting N, S, and T_P following Eq. 1. When the Android application is started, a camera screen (Fig. 5 (i)) is displayed. Next, LED-to-camera communication begins when putting the camera close to the LED. It begins automatically by checking the screen illuminance and the number of rising pulse between detected preambles. In the communication, multiple columns of pixels are referred to demodulate signals to improve the communication range. After the received data is stored in the database. Finally, the data is displayed as a graph (Fig. 5 (ii)).

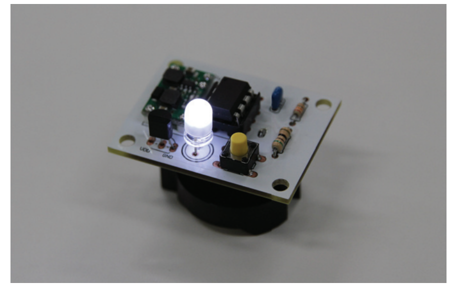

Figure 4. Temperature measurement board. It consists of ATtiny85 as a microcomputer, a 5 mm LED, a temperature sensor, a tact switch, and a power circuit.

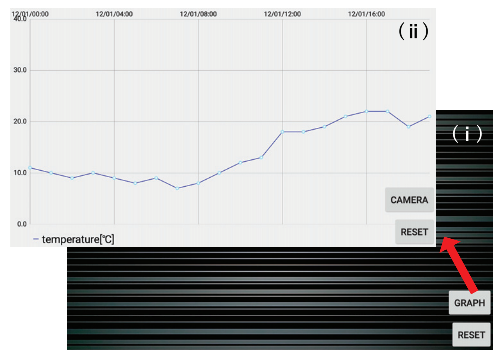

Figure 5. Screenshot of the Android app. This app has a camera mode in which the smartphone performs as a receiver and a graph mode in which the received data is displayed as a graph.

Evaluation: The parameters are set as follows: the length of a symbol is 150 μs, the length of a preamble is 215 μs, and the number of symbols included in a packet is 16 (8 symbols are used as a sequence and the others are used as data). Therefore, T_P, the length of a packet is 2.615 ms. As a receiver, we use ASUS Zenfone 2 Laser ZE601KL whose T_F is 22.2 ms and T_G is 10.6 ms. Finally, following Eq. 1, the two parameters are set as follows: $N = 6$, $S = 2$. In this setting, the achieved throughput reaches 1.53 kbps without data losses.

4 Conclusion

In this work, we propose a reliable and high-speed LED-to-camera communication for smartphones which is suitable for easy access to information-intensive things. With this system, low-cost, small-size, and intuitive connections between things and humans can be realized. As future works, we are working on evaluating this communication method in various environment and implementing the prototypes towards practical applications.

5 References

[1] C. Danakis, et. al: "Using a CMOS camera sensor for visible light communication," IEEE Globecom Workshops 2012.

[2] N. Rajagopal, et. al: "Visual light landmarks for mobile devices," Proc. of IEEE IPSN, 2014.

[3] H.-Y. Lee, et. al: "RollingLight: Enabling line-of-sight light-to-camera communications," Proc. of ACM MobiSys, 2015.

[4] P. Hu, et. al: "ColorBars: Increasing data Rate of led-to-camera communication using color shift keying," Proc. of ACM CoNEXT, 2015.