

Real Time Vital Sign Transmission Using IEEE 802.15.7 VLC PHY-I Transceiver

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Abstract—Visible Light Communication (VLC) Technology is the short range optical wireless communication technology using the light source such as LEDs for data transmission. The major advantage of VLC is that it causes no interference to RF-based devices. This makes wireless communication possible in RF hazardous areas such as in a hospital. In addition, simple installation procedures and band licensing-free characteristic also help to increase VLC's potential to be developed as an alternative, or even a new standard to the wireless communication scheme. For IEEE 802.15.7 VLC standard, it consists of PHY I, II and III operating modes. In this paper, we first focus on analyzing PHY I with OOK modulation, which is targeted towards applications requiring data rate range from 11.67 kb/s to 100 kb/s with 200 kHz optical clock rate. Moreover, we propose the improvement of the real time vital sign transmission based on IEEE 802.15.7 VLC standard using PHY I operating modes for sending the vital signs data, which are temperature and heart rate. This system is improved from our previous system in many terms. The obvious improvement is the communication speed. Moreover, the transmission range is able to be increased by adding the VLC repeater.

Keywords—Visible Light Communication (VLC); optical wireless communication; LED; IEEE 802.15.7 PHY-I

I. INTRODUCTION (HEADING 1)

In recent years, a visible light communication (VLC) is being regarded as a compelling technology in wireless communication field. Low-cost LEDs are also expected to replace the existing fluorescent and incandescent lights and dominate the general illumination market in the near future [1]. This expected wide-scale availability of LEDs opens the door for VLC.

VLC is a wireless communication technology that uses light wave length between 375 nm – 780 nm which is visible to humans as a carrier [3]. VLC provides the simultaneous use of LEDs for both lighting and communication purposes. With a white LED, it can be pulsed at hundreds of megahertz. This qualification makes it possible to transmit data at high speeds, which human eye cannot perceive the light changes [4].

Compared with conventional radio frequency (RF) wireless communications, VLC offers several unique advantages. It has no RF radiation and electromagnetic interference. VLC is a line-of-sight communication which provides high security in communication. Moreover, it uses unlicensed visible light

spectrum with hundreds-of-THz bandwidth and compatibility with illumination infrastructure [5].

There are a few standards for VLC in these days, including 802.11 IP PHY, IEEE 802.15.7 and JEITA CP-1221 [6]. PHY and a MAC layers for short-range optical wireless communications using visible light in optically transparent media are defined in IEEE 802.15.7. The standard is capable of delivering data rates sufficient to support audio and video multimedia services and also considers mobility of the visible link, compatibility with visible-light infrastructures, impairments due to noise and interference from sources like ambient light and a MAC layer that accommodates visible links [7].

The IEEE 802.15.7 standard offers three physical (PHY) types for VLC. PHY I operates from 11.67 kb/s to 266.6 kb/s, PHY II operates from 1.25 Mb/s to 96 Mb/s and PHY III operates between 12 Mb/s and 96 Mb/s. PHY I and PHY II are defined for a single light source, and support on-off keying (OOK) and variable pulse-position modulation (VPPM). PHY III uses multiple optical sources with different frequencies (colors) and uses a particular modulation format called color shift keying (CSK).

In this paper, we will firstly focus on the OOK modulation of PHY I. Even though the data rate is low, it is able to be used with various applications such as a localization using VLC, a commercialization using VLC and a simple wireless communication using VLC in the hospital. After merging the standard with our previous work, a real time vital sign transmission using VLC [8], the data rate is improved by 1000 times. Furthermore, to extend the distance between the transmitter and the receiver, the VLC repeater which was implemented in our previous work [9] is able to be used here for increasing the transmission distance and for avoiding obstacles.

The paper is organized as follows. Section II briefly introduces the PHY I operating modes of the IEEE 802.15.7 standard and discusses on physical-layer data unit (PPDU) and the encoding and modulation. The design and the circuit implementation, as well as the experiment results are presented in Section III. Section IV describes the improvement of the real time vital sign transmission based on IEEE 802.15.7 VLC PHY-I. Section V shows the experiment of vital sign

transmission with a 4-Direction repeater. Finally, this paper is summarized in section VI.

II. PHY-I OPERATION MODES

The specification of PHY I operating modes is shown in Fig. 1. For the OOK modulation, the data rates range from 11.67 kb/s to 100 kb/s, while for VPPM (variable pulse position modulation), the data rates are range from 35.56 kb/s to 266.6 kb/s.

TABLE I
PHY I OPERATING MODES

Modulation	RLL code	Optical clock rate	FEC		Data rate
			Outer code (RS)	Inner code (CC)	
OOK	Manchester	200 kHz	(15,7)	1/4	11.67 kb/s
			(15,11)	1/3	24.44 kb/s
			(15,11)	2/3	48.89 kb/s
			(15,11)	None	73.3 kb/s
			none	None	100 kb/s
VPPM	4B6B	400 kHz	(15,2)	None	35.56 kb/s
			(15,4)	None	71.11 kb/s
			(15,7)	None	124.4 kb/s
			none	None	266.6 kb/s

Fig. 1. Format of the PHY-I operating modes.

A. Physical-layer Data Unit (PPDU)

Following to the physical-layer of the standard, before each data transmission, data must get packed into a physical-layer data unit (PPDU). Each PPDU consists of a synchronization header (SHR), a physical-layer header (PHR), and a PHY service data unit (PSDU). The PPDU format is shown in Fig. 2.

Preamble (see 8.6.1)	PHY header (see 8.6.2)	HCS (see 8.6.3)	Optional fields (see 8.6.4)	PSDU (see 8.6.5)
SHR	PHR			PHY payload

Fig. 2. Format of the PPDU.

The SHR is the preamble field which is used by the transceiver to obtain the optical clock the synchronization with an incoming message. The standard defines one fast locking pattern (FLP) followed by choice of four topology dependent patterns (TDPs) for the purposes of distinguishing different PHY topologies. The FLP is fixed to start as a “1010...” pattern i.e., it ends with a ‘0’.

The preamble field for single data mode shall be formatted as illustrated in Fig. 3. For the burst mode transmission, the FLP shall be included only for the first frame.



Fig. 3. Format of the preamble field.

The PHR consists of a PHY header, a header checks sequence (HCS) and the optional fields.

The PHY header contains many important information for PHY payload, such as the length of PSDU field. This PHY header shall be sent at the lowest data rate for the chosen optical clock rate. Therefore, in this paper, the data rate for PHY header is 11.67 kb/s.

The HCS is a 2 octet CRC-16 of the PHY header. The CRC shall be calculated using the following standard generator polynomial of degree 16 (1). The registers shall be initialized to all ones.

$$G_{16}x = x^{16} + x^{12} + x^5 + 1 \tag{1}$$

The optional field for PHY I with an optical clock rate of 200 kHz is six tail bits of zeroes.

The PSDU field carries the data of the PHY frame or called PHY payload. Six tail bits of zeroes are also attached here, at the end of the PSDU.

B. Encoding and Modulation

For PHY I, concatenated coding is used with a combination of Convolutional Code (CC) and a Reed-Solomon Code (RS). The RS encoder output is padded with zeroes to form an interleaver boundary. The padded zeroes are then punctured and the result is sent to the inner convolutional encoder. In the last step of the scheme, the result from the CC encoder will be sent to the Run Length Limit (RLL) encoder. The PHR and PSDU parts of the PPDU are subject to the FEC for error protection. A reference implementation of the modulator is shown in Fig. 4.

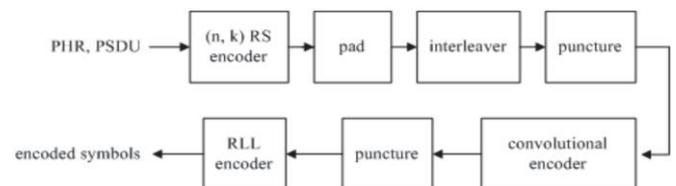


Fig. 4. Reference modulator diagram for PHY I.

III. EXPERIMENT AND RESULT

According to the reviewed papers, e.g. [6], many comparisons of each rule in IEEE 802.15.7 VLC standard are described. Here is one new comparison, which is the comparison of the distance between the transmitter and the receiver of each rule in PHY-I 200 kHz optical rate.

Fig. 5 shows the transmitter circuit which is the same as the transmitter circuit using in our previous work [9].

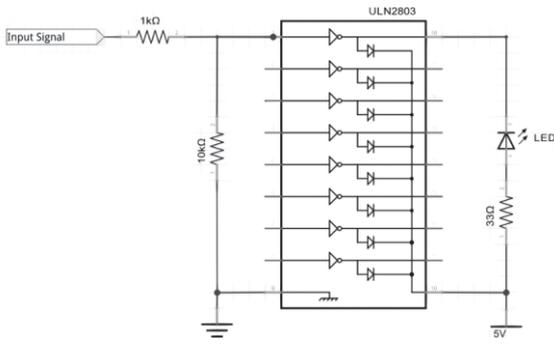


Fig. 5. Schematic of the Transmitter Circuit.

Fig. 6 shows the receiver circuit. This circuit is different from our previous work [9]. SFH203P is using here as the photodiode instead of TSL12S-LF to receive the light more perfectly in straight direction. Nevertheless, using of SFH203P makes the distance between the transmitter and the receiver decreases. To achieve 200 kHz clock rate corresponding to the standard, the dual op-amp is changed from MCP6402 to TSV992AIDT due to the low slew rate of the old one.

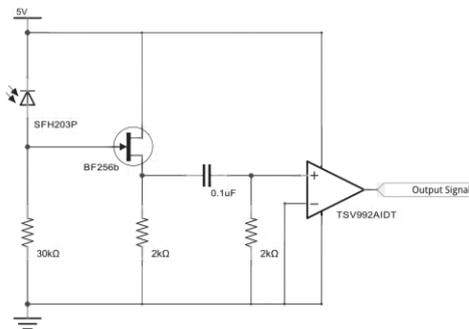


Fig. 6. Schematic of the Transmitter Circuit.

The experimental result of the comparison between the maximum distances of each data rate is shown in Fig. 7. The distance displayed in the graph is the maximum distance between the transmitter and the receiver which makes the system able to transmit and receive data correctly without any average error in 5 sets of data, with 500 random data in each set. The x-axis is the data rate in kb/s, while the y-axis is the distance in centimeter.

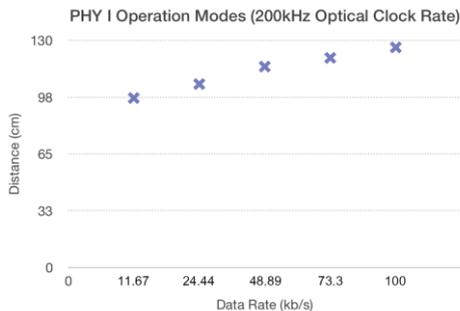


Fig. 7. Comparison between the maximum distance of each data rate.

IV. REAL TIME VITAL SIGN TRANSMISSION

Here, we use the IEEE 802.15.7 VLC standard PHY-I with the previous real time vital sign transmission system [8] to improve the data rate from 1 kb/s to 100 kb/s.

At the transmitter side, the temperature sensor and the heart rate sensor are using here to gather user information. This data will pass through the encoding and modulation schemes for transmitting as a light signal. At the receiver side, the receiver circuit will help to convert the light signal received from the photodiode into data. Next, this data will pass through decoding and demodulation schemes and will display in the receiver side program.

Fig. 8 shows the experiment of the real time vital sign transmission, working perfectly with the data rate of 100 kb/s.



Fig. 8. Experiment of the real time vital sign transmission.

The VLC transceiver program is using in both sides of the system, transmitter side and receiver side. To use this program, the user must first select the COM port, the data type and the data rate. There are two types of data, primary data and secondary data. Choosing of primary data, program will get the real time vital sign data from the sensors. Otherwise, choosing of secondary data, program will get the previously stored data directly from the textbox displayed in the program.

Fig. 9 shows the example of using the program at the transmitter side. The primary data sending here are temperature and heart rate, 37.01 °C and 87 bpm respectively.

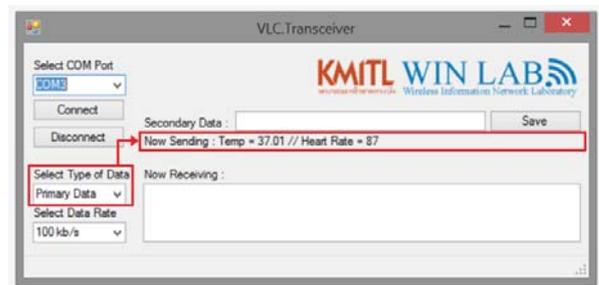


Fig. 9. Program at the transmitter side.

Fig. 10 shows the example of using the program at the receiver side, receiving the data and displaying line by line.

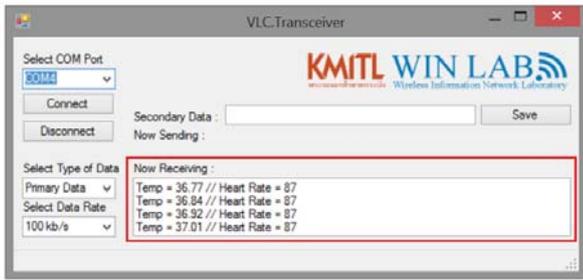


Fig. 10. Program at the receiver side.

V. VITAL SIGN TRANSMISSION WITH A REPEATER

Not only to study on the standard and to increase the data rate of the real time vital sign transmission system, we also try to add the implemented VLC repeater [9] in this improved system to increase the distance between the transmitter and the receiver and to avoid the obstacle in communication. The result of the experiment shows that the addition of the VLC repeater is able to extend the distance perfectly. One of VLC repeater can help increasing the distance of 590 cm.

Fig. 11 shows the example of the experiment using a 4-directional VLC repeater as the repeater in the system.

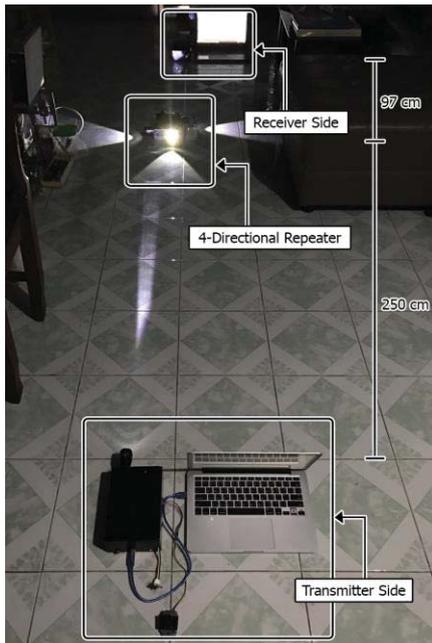


Fig. 11. Experiment of vital sign transmission with a 4-direction repeater.

The temperature and heart rate data is transmitted and received in 100 kb/s using secondary data saved at the transmitter side. With the limit space of the experiment room, the repeater here helps extending the distance of 250 cm instead of maximum length of 590 cm.

VI. CONCLUSION

In this work, real time vital sign transmission using IEEE 802.15.7 VLC PHY-I transceiver is implemented to study the physical layer of the IEEE 802.15.7 VLC standard and to increase the data rate from 1 kb/s of our previous system. Changed of the receiver circuit and the software, the system is able to transmit and receive the real time temperature and heart rate smoothly in 100 kb/s. The comparison between each rule of PHY-I 200 kHz clock rate in term of the distance between the transmitter and receiver shows that the different of distance of each rule is not much, by changing the distance of 1 cm can make big damage to the received data.

In addition, we also added the implemented VLC repeater in this improved real time vital sign transmission system. The result of the experiment shows that the addition of one VLC repeater is able to extend the distance perfectly, maximum of 590 cm.

For the future work, we plan to study more on the IEEE 802.15.7 VLC standard. The next and next layer will be included in the system, the MAC sublayer and the MAC layer.

ACKNOWLEDGMENT

This research work is financial supported by King Mongkut's Institute of Technology Ladkrabang.

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