LED-ID Systems Applying the Modulation and Coding Selection Based on Received Angle

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Abstract

This paper proposed the Modulation and Coding Selection (MCS) scheme according to the received angle in LED-ID optical wireless system. If location of LED-ID receiver is different, the optical power of received signal is different due to the received angle in LED-ID system. Therefore, system performance varies as the receiving angle changes, affecting the stability of the whole system. In the implemented LED-ID transceiver with 400Mbps data rate, a combination of convolutional code and variety modulation order such as BPSK, QPSK, 16QAM, 64QAM is adaptively changed based on the received power according to received angle in the LED-ID channel. The proposed system can achieve improved throughput in comparison to those of conventional LED-ID systems, as well as a superior target bit error rate (BER).

Keywords: *LED-ID, Modulation and Coding Selection (MCS), Received angle, Visible Light Communication (VLC)*

1. Introduction

Recently, visible light communication (VLC) systems have attracted attention due to progress in the field of visible light technology [1]. Visible light has several attractive features distinct from those of radio frequency (RF) and infrared (IR) [2]. LED and laser diodes (LD) are usually used as optical sources, but LEDs are preferred as strong candidates for the next generation lighting technology for several reasons including fewer safety concerns, a relatively long useful life time, and a wider emission angle than those of LDs. As a transmitter for optical wireless communication, LED lights emit visible rays as the medium of data transmission [4].

As for the identification (ID) systems, the typical method in communication is to use radio frequency (RF) as the medium transmission and it is known as RFID. Nevertheless, with the development of VLC systems, both the industrial and scientific communities have recognized that LED lights can be used in ID systems, called as LED-ID [5]. The LED-ID is an automatic technology aiding machines or computers to identify, record, or control individual target via visible lights. A LED-ID system includes at least two components, LED-ID reader and LED-ID tag. The LED-ID reader receives required information from the LED-ID tags. LED-ID has the following advantages compared to those of RFID such as high tag-ID efficiency in a dense tag environments, visible light is harmless to our health, friendly user interface and low power consumption.

There are many researchers concerning optical wireless communication which address the ISI caused by multipath dispersion using methods such as equalization [4]. However, they don't consider that the received power is related to the incidence angle of the receiver, which is usually defined as a gain of 1. In a realistic LED-ID model, the angle of the incident light is not fixed, which means that the received power varies [5]. Therefore, system performance is changed when received power is varied.

In order to maintain steady communication performance, we use modulation and coding selection technology (MCS), an alternative link adaptation method that has been widely used in third generation mobile wireless communications [6]. MCS is defined as the ability to match the modulation-coding scheme to the average channel conditions of each user while holding the power of the transmitted signal constant over a frame interval.

In LED-ID, the modulation order and coding rate are changed in order to match the currently received signal level. In addition, it is possible to dynamically change the modulation and coding scheme for variably received optical power, according to the measured incident angle at the receiver. The high received optical power a high order modulation scheme with low coding rate is used in order to increase the data rate of the transmission, in contrast, low received optical power, the system selects a modulation scheme and a coding rate of lower order to maintain both connection quality and link stability without the need of increasing the signal power.

This paper proposed the Modulation and Coding Selection (MCS) scheme according to the different received angle in LED-ID optical wireless system. This system aims to maintain steady communication and maximize the total throughput while satisfying predefined threshold over various channel conditions. For evaluation, we use the 4-type modulation order such as BPSK, QPSK, 16QAM and 64QAM. Also, we use the convolutional code with coding rates of 1/3, 1/2, 2/3 and 3/4, respectively.

The paper is organized as follows: Section 2 describes the LED-ID optical wireless channel, Section 3 operational principle of the proposed MCS in LED-ID, Section 4 presents a simulation parameters and results, and Section 5 provides concluding remarks.

2. LED-ID Optical Wireless Channel

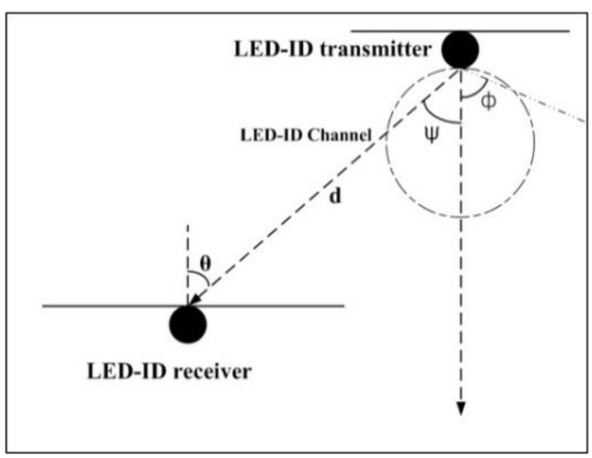

Figure 1. LED-ID Optical Wireless Channel

This section is going to explain about the channel model in LED-ID. In the wireless optical channel, the illumination source is fixed at the location and also the radiation pattern of LED is determined by the characteristic of the type of LED. When the position of the receiver is moved, the angle of incidence varies sequentially which related to the received power depending on the optical filter gain. The differences of the optical filter gain has influenced to the BER performance according to the variation of the received signal power intensity. Therefore, the location information of receiver serves as the most important factor to analyze the performance of the LED-ID transceiver. Figure 1 shows the LED-ID optical wireless channel. The received power P_r is related to illumination of LED light [4]. Therefore, we express the received power by illumination as follow,

$$P_r = \frac{I \cdot \cos(\psi)^n \cdot \cos(\theta)}{d^2} \tag{1}$$

where, I is the center luminous intensity of an LED, ψ is the angle of incidence, θ is the angle of incidence, and d is the distance between an LED-ID transmitter and LED-ID receiver. In this paper, LED chip for LED-ID transmitter has a Lambertian radiation pattern [5]. Therefore, received power P_r depends on the angle of incidence, θ. n is the order of Lambertian emission, and is given by the semi angle at half illuminance of LED ϕ as $n = -\ln 2 / \ln(\cos\phi)$. In this paper, we use the 60 degree to make the n equal to 1.

Figure 2 shows relative optical filter gain according to the angle of incidence. We use a single thin dielectric layer filter in our receiver model [7].

The refraction formula is shown below:

$$\frac{\sin\theta}{\sin\theta'} = \frac{n_1}{n_2} \tag{2}$$

where n_1 is the refractive index of the vacuum, n_2 is the refractive index of the concentrator, and θ and θ' are the incidence angle and refraction angle, respectively. When the incident angle is less than 60 degrees, there is no distinct degradation, however, when the incident angle is larger than 60 degrees, degradation is very severe. If we use the fixed modulation and coding rate, it is difficult to maintain the BER performance for the rapidly decreasing relative gain of the optical filter. Therefore, our proposed system adaptively selects the modulation and coding rate to improve throughput performance and to maintain the BER performance. In this paper, we operate the MCS scheme from 60 degree to 90 degree for maintain the BER performance.

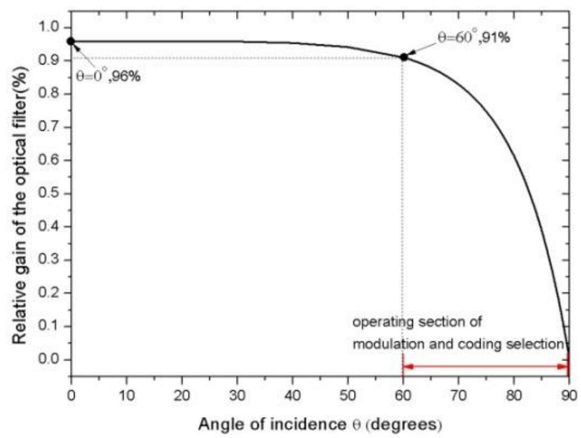

Figure 2. The relative optical filter gain according to the angle of incidence. ($n_1 : n_2 = 1 : 1.5$)

3. Operational Principle of MCS in LED-ID

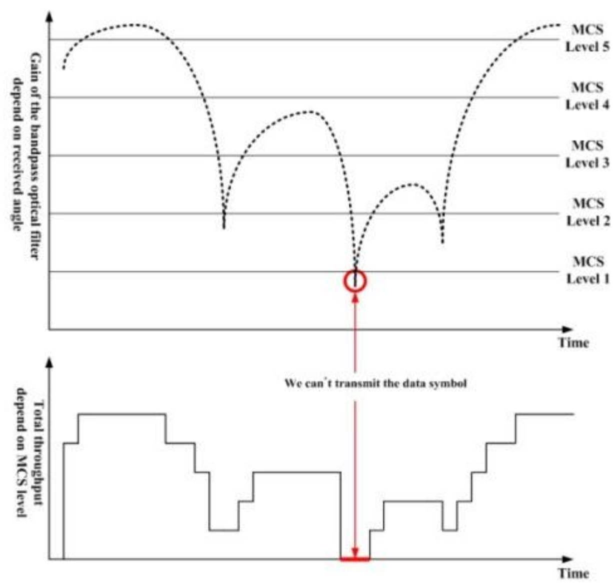

Figure 3. Operating principle of MCS in LED-ID

Figure 3 illustrates the operational principle of the proposed MCS in LED-ID. In the optical wireless channel, the received power varies according to the received angle that depends on the location of the receiver. It is difficult to maintain the system stability since the receiver is not stationary. Therefore, an efficient modulation and coding selection technique is needed for maintaining the system performance. Figure 3 shows that total throughput by selecting MCS level when gain of the band pass optical filter is changed. The modulation order and channel coding rate are adaptively controlled by gain of the band pass optical filter according to received angle.

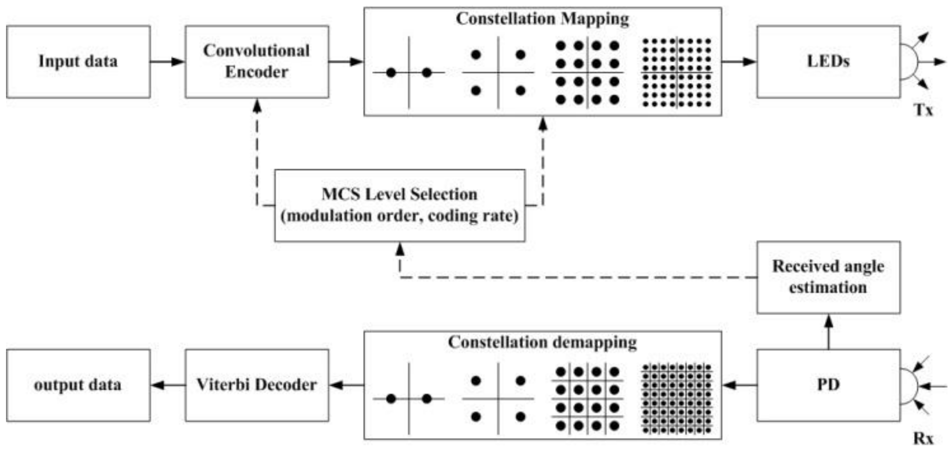

Figure 4. Structure of transmitter and receiver of LED-ID with MCS scheme

Figure 4 shows the system schematic diagram of the transmitter and receiver of LED-ID with MCS scheme. The user's input bits are encoded by using convolutional coding with coding rate of 1/3, 1/2, 2/3 and 3/4. After encoding, the coded symbols are modulated by BPSK, QPSK, 16QAM and 64QAM according to the received angle estimation. After the signals are transmitted through the IM over a wireless optical LED-ID channel and then are received at the LED-ID receiver. The LED-ID channel can be expressed as additive white Gaussian noise (AWGN). The received signal is given by,

$$y(t) = r \cdot x(t) \otimes h(t) + n(t) \tag{3}$$

where $y(t)$ represents received signal, $x(t)$ and $n(t)$ are represented transmitted optical pulse and AWGN noise, respectively. r is and optical/electric (O/E) conversion efficiency. $\otimes$ means the convolution.

The LED-ID receiver receives the transmitted signal by using photo detector. From photo detector, we can estimate the received power and calculate the received angle at this time.

From equation (1), we can draw the incidence angle θ.

$$\theta = \cos^{-1}\left(\frac{P_r \cdot d^2}{I \cdot \cos(\psi)^n}\right) \tag{4}$$

Thus, we can calculate the relative optical filter gain by using the incidence angle θ.

Figure 5 illustrates the MCS algorithm in LED-ID system in details. It is assumed that the transmitter can be offered via feedback the received angle value from the receiver. The received angle is feedback to modulation and channel scheme selector. MCS selector modifies transmission parameters, coding rates and modulation scheme, based on the received angle at the LED-ID receiver. The LED-ID receiver performs demodulation and decoding by using Viterbi decoding. Finally, we can recover the input data.

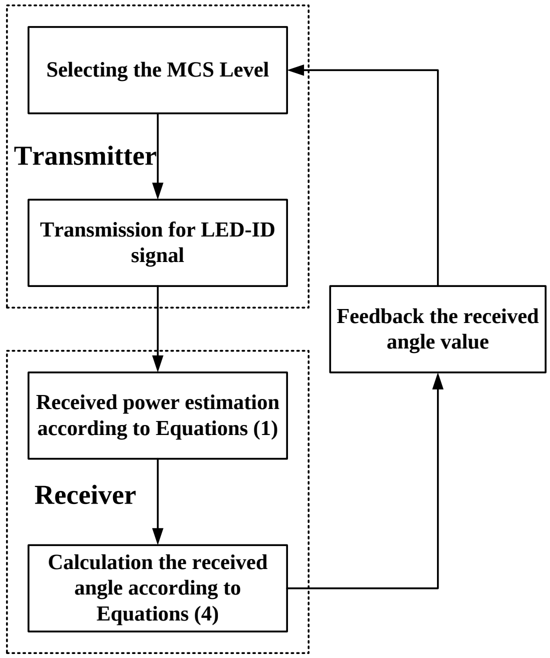

Figure 5. The modulation and coding selection algorithm in LED-ID system

Table 1. MCS level for modulation and channel coding rate

MCS Level	Modulation	Coding rate	Maximum data rate (Mbps)
1	BPSK	1/3	133.3
2		1/2	200
3		2/3	266.6
4		3/4	300
5	QPSK	1/2	400
6		2/3	533.2
7		3/4	600
8	16QAM	1/2	800
9		2/3	1066.4
10		3/4	1200
11	64QAM	2/3	1600
12		3/4	1800

The data rate of each MCS level is shown in Table 1. In the LED-ID MCS scheme, the data transmission rate of each MCS level increases proportionally to the higher modulation orders and higher coding rates. There are many references in the selection of the MCS level threshold. In this paper, by threshold we refer to the target BER needed in order to support the system’s performance. Therefore, we assume that the system allows us to maintain a steady performance, which depends on the threshold value determined by the MCS level selection. We selected the MCS level in order to achieve maximum throughput over the satisfied threshold. The throughput is defined as the sum of the successfully-received data rates.

$$Throughput \quad \eta = (1 - BER) \times Symbol\, rate \times \log_2 M \times Coding\, rate$$

4. Simulation Parameter and Results

Table 2 shows the simulation parameters. The channel is assumed to be LED-ID indoor channel model [6]. In this model, the occurrence of one Lambertian is assumed. Intensity Modulation and Direct Detection (IM-DD) are used as the optical modulation scheme. BPSK, QPSK, 16QAM and 64QAM are used as a pulse modulation. The noise is assumed to be an AWGN and the transmission distance is 1.0m.

Table 2. Simulation parameter

Modulation Scheme	IM-DD	
Pulse Modulation	BPSK	QPSK
	16QAM	64QAM
Multiplexing Method	WDM	
Symbol rate R_b	400 Mbps	
Noise Model	AWGN	
FEC	Convolutional, R=1/3, 1/2, 2/3, 3/4	
Transmission distance : d	1.0 m	
Background light noise	0 dBm	
O/E covert efficiency	0.52	

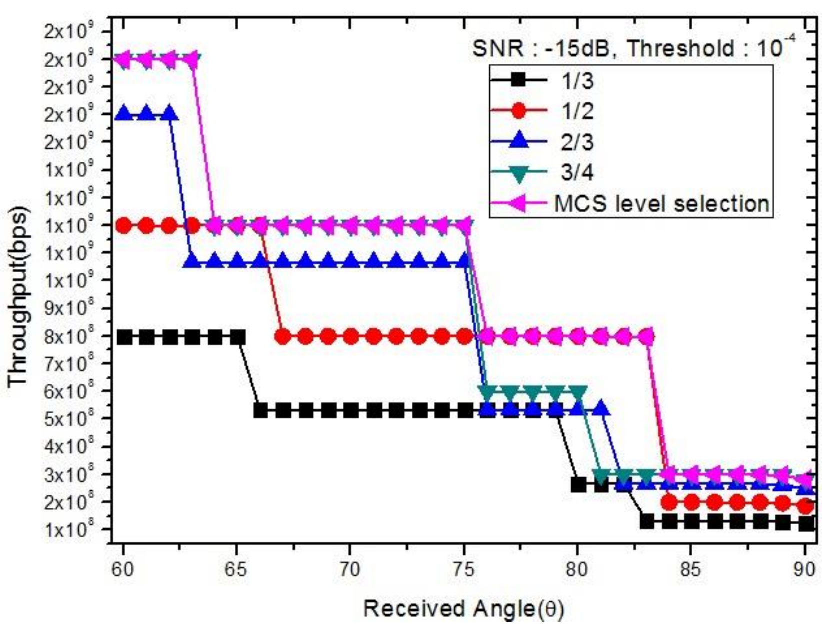

Figure 6. Throughput performance of the LED-ID system when the received angle varies from 60 to 90 degrees

Figure 6 shows the throughput performance of the LED-ID system when the received angle varies from 60 to 90 degrees. In the simulation, the throughput of the LED-ID system changes depending on the modulation order and coding rate. We considered a fixed coding rate and various modulation orders according to received angle for the conventional system. On the other hand, the proposed system uses various coding rates and modulation orders.

Additionally, it can be seen that the throughput performance of the LED-ID system is degraded when the received angle increases because the high received angle represents low relative gain on the optical filter. In contrast, throughput is increased when the received angle is decreased. By using low modulation orders and low coding rates for a low received angle, the system becomes very inefficient. Therefore, we need to use the MCS level selection scheme for efficiently improving the throughput performance. It adaptively changes the MCS level in order to improve the throughput according to the received angle. It can be seen from the previous figures that by applying the MCS level selection scheme, we obtain a higher throughput compared to those of conventional systems. Therefore, we can conclude that the MCS level selection scheme is effective in enchaining the throughput in LED-ID optical wireless communication channels.

5. Conclusion

In this paper, we proposed a modulation and coding selection scheme in a LED-ID system. We evaluated the throughput performance of the proposed system and the conventional system under the same conditions. The proposed system was able to deal with various received angles; therefore, demonstrating better performance compared to that of the conventional system. The proposed system is effective in providing the necessary high quality services required for LED-ID optical wireless communication channels.

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