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Group statistical channel coding dimming scheme in visible light communication system

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ABSTRACT

In this paper, we propose a group statistical channel coding (GSCC) scheme, which achieves dimming by changing the ratio of the 0–1 symbol of the original data stream through probabilistic statistics method. The simulation under various brightness conditions displays that the GSCC maintains good performance comparing to PWM dimming with half satisfice of transmission rate and a larger dimming intensity. Simulation of GSCC after combining with other channel coding schemes reflects that GSCC has good compatibility to arbitrary access coded signal.

1. Introduction

Recently, the white light emitting diodes (LED), which have a lot of desired properties such as lower power consumption, long lifetime, small size and cool operation, are promised to be the future lighting devices. The visible light communication (VLC) based on LED, has been researched extensively as the next generation indoor high rate data communication [1–4]. In indoor illumination, different luminance is required in different scenarios. Thus, VLC is supposed to provide variable illumination in different scenarios while maintaining efficient communication. Therefore dimming is combined with VLC. Many dimming methods are proposed by researchers, OOK and PWM dimming e.g. However, these methods have many limits on dimming rate and transmission rate while sustaining enough signal to noise ratio (SNR) and bit error rate (BER). To overcome these problems, the research of the appropriate coding dimming mechanism in VLC system obtains widespread attention. The coding dimming mechanism changes the ratio of the 0–1 symbol of the original data stream through appropriate coding scheme, thereby changes the average irradiation power of the LED to fit different brightness demand.

The current research on the indoor VLC dimming using channel coding is still rare. Most of the research is a transplant of wireless communication channel coding technology, such as LDPC codes [5], bipolar binary code [6], and turbo code [7]. These research achieves dimming by puncturing and compensating code. Some other researchers propose the pulse position coding dimming based on balanced incomplete block design [8–9]. This scheme achieves high transmission rate and dimming through altering the comprehensive weight of different codes. However, it's relatively difficult to realise with a poor performance in a practical application.

In this letter, we first introduce the group statistical channel coding scheme based on the VLC system model. Then we compare the performance of the OOK and PWM modulation schemes with the proposed dimming coding method applied in VLC systems in terms of bandwidth, power requirement, and BER performance according to dimming rate.

2. Group statistical channel coding scheme

2.1. System model

The system structure is presented in Fig. 1. A line of sight link, additive white Gaussian noise channel (AWGN) was assumed, and the light link is seldom blocked. The transmitter is the LED which the electrical signal is transformed into white light signal, the changing light strength information expresses the transmitted signal. In the receiver, the PD transforms light signal into electronic signal.

In Fig. 1, we show VLC system structure with the dimming-coding section. The signal source which is a binary bit stream is transformed to dimming-coding section to fit the demand of the illumination. After modulated and transmitted in the channel with the supposed noise AWGN, The signal is then decoded in the

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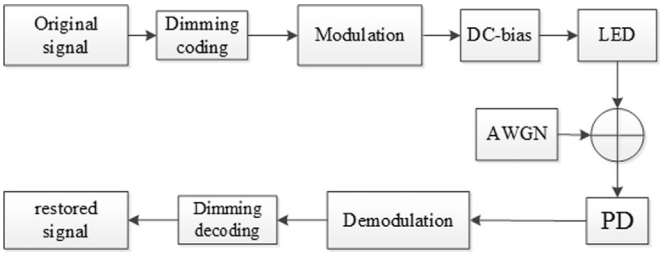

Fig. 1. VLC system structure with dimming section.

receiver after the demodulation to restore the original signal.

2.2. Principle of GSCC

Channel coding is a widely applied technology in wire and wireless communication. Through channel coding, the reliability of the transmission system can be guaranteed. In VLC, the brightness of the LED can be determined by the average power of the signal. Dimming can be achieved by adjusting the average power of the signal through channel coding. At present, study progress of the dimming through channel coding is expected more improvement. Most studies about this technology are just transplants of the channel coding in traditional mobile communication as a tentatively theoretical research. This paper has found a peculiar and effective method. The signal is coded in a specific algorithm to maintain communication system's function under different luminance of the LED while keeping low influence on the efficiency and the reliability and the transmission capacity of the communication system.

The coding process is described in Fig. 2. Firstly, the dimming codes are obtained after analysing the desired 0–1 symbol proportion in terms of dimming rates. The dimming code is proposed here to encode the original signal. The weight of the signal code is reallocated through operation with the dimming code, then the processed signal is transmitted to channel. In the receiver, the signal is decoded by the reverse operation with the dimming code, recovered to the original signal. The decoding of the signal is showed in Fig. 3.

In Fig. 2, the input bit stream s {s1, s2, s3, s4} derives from the original signal after the serial/parallel conversion. Code group g1 {g11, g12, g13, g14} and g2 {g21, g22, g23, g24} are the dimming code corresponding to specific dimming rate d. The code weight of g1 and g2 is determined by following formulation:

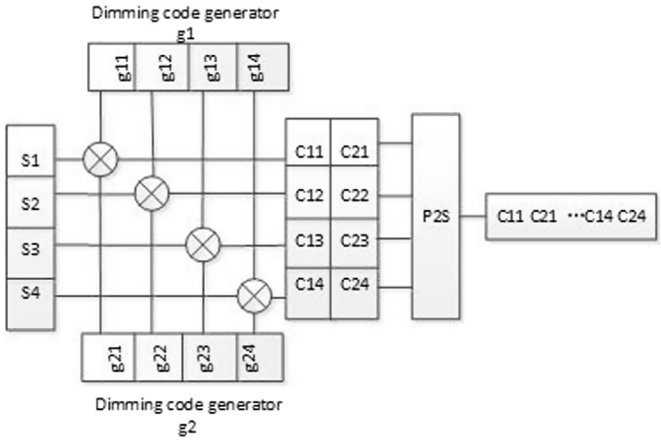

Fig. 2. GSCC encoder principle.

$$W_{g1+g2} = \begin{cases} \dfrac{L_{g1+g2}\,d}{p}, & 0 \le d \le 0.5 \\ \dfrac{L_{g1+g2}(1-d)}{p}, & 0.5 < d \le 1 \end{cases} \quad (1)$$

where p represents the occurrence probability of '1', and L_{g1+g2} represents length of g1 plus g2. Also, for maintaining each bit of original signal, the result of g1 bitwise OR with g2 should be [1 1 … 1]. The operator ⊗ in Fig. 2 means an bitwise AND operation. The input stream s bitwise AND with g1 and g2 to obtain c1 {c11, c12, c13, c14} and c2 {c21, c22, c23, c24}. The final output code c {c11, c21, c12, c22, c13, c23, c14, c24} is combined by c1 and c2 after a parallel/serial conversion to each of those two sequence.

In Fig. 3, y {y11, y21, y12, y22, y13, y23, y14, y24} is the stream received by the receiver of VLC system. The decoding circuit firstly separate y into y1 {y11, y12, y13, y14} and y2 {y21, y22, y23, y24}, then converse y1 and y2 to multi-line parallel stream. The circuit generates the same dimming code g1 and g2 in terms of the average weights of y1 and y2. y1 and y2 bitwise OR with g1 and g2 respectively to get d1 {d11, d12, d13, d14} and d2 {d21, d22, d23, d24} after g1 and g2 bitwise NOT themselves, d1 bitwise AND with d2 to obtain final output, the original signal *s*. In the principle figure, the signal is coded every four bits. This is changeable, increasing the quantity of g1 and g2 may increase the dimming range or compress the interval between dimming rates. The dimming rate can be determined by the proportion of 0–1 symbol. By inverse the signal code, a new proportion can be obtained, therefore the dimming range can be extended twice theoretically.

GSCC is a coding dimming scheme, which can be combined with other channel coding scheme, turbo, LDPC, i.e. to increase the BER performance. In former research, dimming scheme based on turbo, LDPC and other channel coding technologies achieve dimming through puncturing and compensating code word to change the ratio of symbol '1' and '0'. The puncturing and compensating methods change the internal structure of code word, which recedes the BER performance. GSCC redistribute the original code word without impact to its' internal structure. Since GSCC has universality versus other coding dimming scheme, it's more suitable to apply in access VLC network to match different channel coding scheme.

3. Simulation and results analysis

3.1. Simulation of GSCC and results analysis

This scheme achieved dimming through reallocating the original signal stream to change the 0–1 symbol ratio. Table 1 describes a 4-input 8-output dimming coding scheme, the dimming range is 0.25∼0.75. The four lines in black bold fonts are obtained by inversing the code after operating with g1 and g2.

The simulation environment set as follow: the transmitter employs daily domestic LED and the rated power of a single LED is 0.5 W, the receiver employs Hamamatsu avalanche photo diode, the effective receiving area is 3 mm*3 mm, responsivity is 0.5 A/W. The simulation model is set up as showed in Fig. 1.

Fig. 4 shows the relationship between SNR and System BER in different dimming rate. It's obvious to see from the figure, to maintain the required BER with dimming rate increasing, SNR should be enhanced gradually. As the dimming rate increases, the luminance of the LED increases, therefore the signal power received by APD increases. SNR is enhanced by the dimming system naturally as the dimming rate increases. The entire system performance can be maintained steadily. In Fig. 4(a), the dimming rate can be changed from 0.25 to 0.75 with an interval of 0.0625. In