Optics Communications 353 (2015) 1–5

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Color coded multiple access scheme for bidirectional multiuser visible light communications in smart home technologies

Samrat Vikramaditya Tiwari, Atul Sewaiwar, Yeon-Ho Chung*

Department of Information and Communications Engineering, Pukyong National University, Republic of Korea

ARTICLE INFO

Article history:
Received 13 February 2015
Received in revised form
26 April 2015
Accepted 4 May 2015
Available online 6 May 2015

Keywords:
CCMA
Bidirectional VLC
Smart home
Multiuser

ABSTRACT

In optical wireless communications, multiple channel transmission is an attractive solution to enhancing capacity and system performance. A new modulation scheme called color coded multiple access (CCMA) for bidirectional multiuser visible light communications (VLC) is presented for smart home applications. The proposed scheme uses red, green and blue (RGB) light emitting diodes (LED) for downlink and phosphor based white LED (P-LED) for uplink to establish a bidirectional VLC and also employs orthogonal codes to support multiple users and devices. The downlink transmission for data user devices and smart home devices is provided using red and green colors from the RGB LEDs, respectively, while uplink transmission from both types of devices is performed using the blue color from P-LEDs. Simulations are conducted to verify the performance of the proposed scheme. It is found that the proposed bidirectional multiuser scheme is efficient in terms of data rate and performance. In addition, since the proposed scheme uses RGB signals for downlink data transmission, it provides flicker-free illumination that would lend itself to multiuser VLC system for smart home applications.

1. Introduction

Advancement in recent technologies has extended the demand to higher speed data access. With rapidly congesting RF bands, optical wireless communication (OWC) technology is considered a future candidate to fulfill the need for increasing data rates in wireless communication applications [1]. Due to the increase in popularity of light emitting diode (LED) as a lighting source, it is convenient and easy to provide in-home and in-building visible light communication (VLC) using the already existing LED lamps. Distinct to any other wireless communication systems, VLC has the uniqueness of allowing functionalities of illumination and communication simultaneously with other several advantages such as cost-effectiveness, high security, license-free and electromagnetic interference-free transmission. Researches in such VLC systems have largely been focused on providing single-user communication links with substantial performances [2–6]. Also, the IEEE 802.15.7 standard for VLC addresses a point-to-point communication scenario, but it does not contemplate multiuser (MU) bidirectional transmission yet [7].

For MU bidirectional transmission scenarios in VLC, few works have been reported in the literature. In [8,9], the authors suggested CSK based downlink MU schemes, but the proposed schemes lack bidirectional transmission functionality. In [10], researchers addressed a bidirectional VLC transmission using time division duplex (TDD) under a single user scenario. Recently, the authors proposed a user allocation scheme for the bidirectional multiple access of VLC network [11]. This scheme limits the user allocation to a particular color cluster. Thus, it is not suitable for smart home environments where mobile data users are often expected. Hence, there is a need for rigorous full duplex bidirectional VLC systems for smart home applications.

For efficient smart home technologies, we propose a new color coded multiple access (CCMA) based VLC scheme that supports bidirectional MU communication using red, green and blue (RGB) LEDs for downlink and phosphor based white LEDs (P-LEDs) for uplink. In the proposed scheme, simultaneous data transmission for all users (data user devices and smart home devices) is achieved by transmitting orthogonally separated data streams in different color beams. During the transmission, the RGB components are balanced so as to maintain the color of emitted light as white [12]. The downlink transmission for data user devices and smart home devices is provided using red and green color, respectively. At the receiver, the color filters identify respective colors and photodetectors provide output as individual voltage proportional to the intensity of each color. For the uplink transmission from both types of devices, a P-LED that uses a blue emitter is employed. That is, the data transmitted using the P-LEDs are filtered using the blue color filter.

The proposed multiuser scheme employs different colors for

* Corresponding author. Tel.: +82 51 629 6236.
E-mail address: yhchung@pknu.ac.kr (Y.-H. Chung).

http://dx.doi.org/10.1016/j.optcom.2015.05.012
0030-4018/

the separation of users and devices. The use of different colors allows separation between user data (red) and device data (green) for downlink, and devices/users (blue) for uplink; hence it dramatically increases the data speed that is usually not achievable from other access schemes such as code division multiple access (CDMA) and time division multiple access (TDMA). Therefore, the proposed VLC based scheme proves to be effective for smart home applications where multiple data user devices and smart home devices need full duplex bidirectional communication links. Simulations are carried out to evaluate the performance of the proposed CCMA scheme.

Section 2 describes the proposed system model for CCMA and simulation results are presented and discussed in Section 3. Finally, Section 4 presents conclusions.

2. System description

2.1. CCMA system model

The proposed pure visible light based CCMA model for smart homes is shown in Fig. 1. Any smart home application requires data transmission for two types of devices: data user devices and smart home devices. To this end, we transmit the data for these devices using different color streams so as to provide adequate data rates to data user devices along with efficient control of smart home devices. That is, the transmission for data user devices is done using red color, while for smart home devices, green color is used.

The proposed communication system utilizes individual color channels [8], instead of CSK color coding transformation [7]. Also, we support multiuser bidirectional data transmissions with multiple access features using orthogonal Walsh codes in an indoor VLC environment. In the proposed system, we utilize red and green color bands of a RGB LED for downlink transmission while the blue color from a P-LED is preserved for uplink transmission.

At the input of the transmitter, an orthogonal code sequence is assigned to each user where b_k data bits stream of N individual users are spread as per the code length. We employ a code length (L) of 8 for downlink transmission during simulations. This code length can be increased to 16, 32, etc. to support a larger number of data user devices or smart home devices in an indoor VLC environment.

The data of N users in different channels after spreading are multiplexed to form a serial data stream and transmitted simultaneously. The transmitted spreaded data for kth user is given by

$$x_k(t) = \sum_{i}^{N} a_k(i) \sum_{j}^{N} b_k(j) h(t - ijT_c) \tag{1}$$

where $a_k(i)$ represents the kth channel's information sequence, b_k is the code for kth channel, $h(t - ijT_c)$ is the spreading function. The spread parallel data chips of N channels are multiplexed to form a serial data stream. This serial data stream is then modulated in the modulation block and transmitted using RGB LEDs. Fig. 2 depicts the data transmission and reception of the scheme. It can be observed from Fig. 2 that the red and green color beam of a RGB LED is used to carry the data of user devices and smart home devices respectively, while the blue color beam is provided with the average DC bias to maintain white color for an illumination purpose [8].

For a code multiplexed signal with code length L, chip duration T_c is related to bit duration T_b by

$$T_c = T_b / L \tag{2}$$

Due to time delay and multipath fading from reflection during transmission, the orthogonal codes could suffer from code induced interference in the form of intersymbol interference (ISI). To avoid the effect of ISI at the receiver, we have kept the chip duration (T_c) to 2 ns, which is sufficiently long enough to avoid the delay effect since the propagation delay after first reflection is known to be 1.9 ns in a typical indoor environment [2]. However, it should be noted that the maximum propagation delay depends on the geometry of the room and wall material and therefore the chip duration needs to be changed accordingly for avoiding the ISI. In the present study, it is assumed that the receiver is synchronized with the transmitter for the reception of transmitted data. Therefore, it is implied that data bits are transmitted in frames for both directions of transmission according to the format described

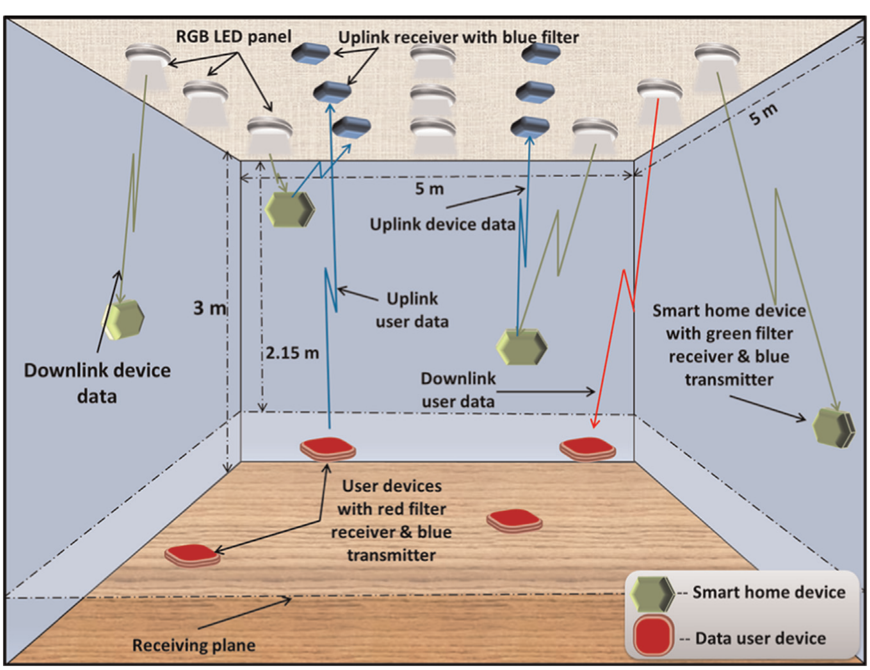

Fig. 1. Proposed CCMA VLC based smart home system.