Optical Switching and Networking 15 (2015) 75–86

Contents lists available at ScienceDirect

Optical Switching and Networking

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

Smart color channel allocation for visible light communication cell ID

Nam-Tuan Le*, Yeong Min Jang

Department of Electronics Engineering, Kookmin University, Seoul, Republic of Korea.

ARTICLE INFO

Article history:
Received 14 February 2014
Received in revised form
23 June 2014
Accepted 23 June 2014
Available online 2 July 2014

Keywords:
Visible light communication
VLC Cell ID
Multi-channel
Cognitive
IEEE 802.15.7

ABSTRACT

In wireless communication network, multi-channel communication technology is a promising solution for throughput performance enhancement and collision avoidance. Similarly with visible light communication, multi-channel approach will show more advances due to the limitation of color channel and co-channel interference at the photo detector. In this research, we proposed a new color channel allocation for visible light communication Cell ID based on IEEE 802.15.7 specification. The proposed scheme is based on feedback channel information, channel priority and cognitive technique. We hope that with the flexibility, efficiency, and reliable scheduling of cognitive issue, it proves to a promising technology for future wireless network generally and especially visible light communication. The numerical results and experimental implementation show the enhancement of signal-to-noise ratio, blocking probability, and CCA time.

1. Introduction

In the field of indoor wireless networks, visible light communication (VLC) is a new technology of wireless communication, which can support both illumination and data transmission using visible light. There are more and more applications in indoor/outdoor using visible light from lighting as a communication medium. Typical transmitter used for visible light communication is visible light LED and the receiver is photodiodes or image sensors. The communication channel is defined as the color bands or wavelengths. The channel will be classified by the intensity variation of three basic colors, RGB. Then depending on the sensitive and characteristic of Photo detector and light source, the visible color band will be classified in N color channel for the communication system. Despite the large visible light band, with the limitation of frequency response of photo detector, switching response of LED and color band interference, color band utilization is one of the challenging issues for visible light communication. In traditional Radio Frequency wireless communication, resource underutilization or spectrum scarcity is one of the most often considerations of the radio spectrum. There is a significant amount of unused allocation radio spectrum due to non-uniform demand strategies of frequency and time or static spectrum allocation policies. The cognitive radio is the matched solution for that problem. Efficient allocation of free spectrum with interfering management with the current allocated channel can increase the total bandwidth of the frequency spectrum.

Standardizing since 2011, IEEE 802.15.7 is one of official specifications for visible light communication. The IEEE 802.15.7 standard defines a PHY layer and medium access control (MAC) layer for visible light communication. The architecture is defined in terms of a number of blocks in order to simplify the standard. These blocks are called

* Corresponding author.
E-mail addresses: namtuanlnt@gmail.com (N.-T. Le), yjang@kookmin.ac.kr (Y.M. Jang).

http://dx.doi.org/10.1016/j.osn.2014.06.005
1573-4277/

layers. Each layer is responsible for one part of the standard and offers services to the higher layers. A VLC WPAN device comprises a PHY, which contains the light transceiver along with its low-level control mechanism, and a MAC sublayer that provides access to the physical channel for all types of transfer. The PHY layer can support three PHY types: PHY I, PHY II and PHY III. PHY I is intended for outdoor applications with low data rates. PHY III is focused on multiple light sources and detector applications with high data rate. For outdoor applications based on PHY I and PHY II, it is necessary to apply concatenated coding which is a combination of convolutional code and Reed Solomon. An IEEE 802.15.7-compliant device must implement either PHY I or PHY II type. A device implementing the PHY III type shall also implement PHY II mode for co-existence. The detail of data rates and constrain between optical clock rates and error correction codes is also defined for supporting a broad class of LEDs for various applications. Depending on the application requirements, an IEEE 802.15.7 WPAN may operate in one of the three topologies: the peer-to-peer topology, the star topology, or the broadcast topology. The peer-to-peer topology also has a coordinator; however, it differs from the star topology in that any device may communicate with any other device as long as they are within range of one another. Apart from the two topologies, IEEE 802.15.7 devices may also operate in a broadcast only mode without being part of a network, without being associated to any device or having any devices associated to them. Star networks operate independently from all other star networks currently in operation. This is achieved by choosing a WPAN identifier that is not currently used by any other network within the radio sphere of influence. Once the WPAN identifier is chosen, the coordinator allows other devices to join its network. In a peer-to-peer topology, each device is capable of communicating with any other device within its VLC transmission sphere of influence. One device is nominated as the coordinator, for instance, by virtue of being the first device to communicate on the channel. Further network structures are constructed out of the peer-to-peer topology and it is possible to impose topological restrictions on the formation of the network.

The architecture of VLC cell and the structure of the multi-color channel cell are presented in Figs. 1 and 2 [1]. A VPAN device comprises a PHY layer, which contains the light transceiver along with its low-level control mechanism, and a medium access control (MAC) sublayer that provides access to the physical channel for all types of transfers. The DME can also control the PHY switch using the PLME for selection of the optical sources and

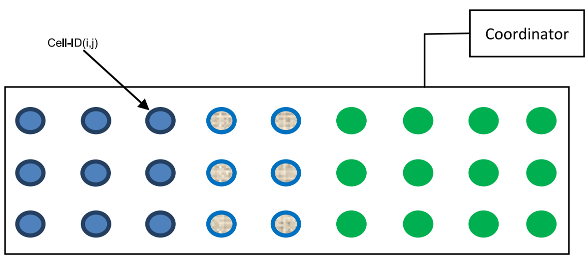

Fig. 1. VLC Cell ID topology.

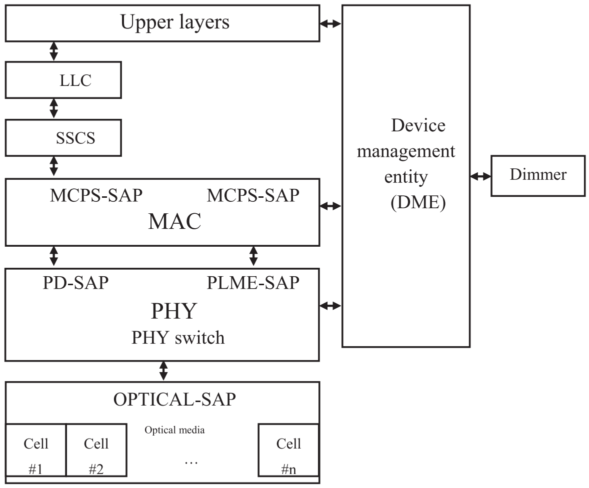

Fig. 2. VPAN device architecture.

photodetectors. The details of the DME are outside the scope of this standard. The PHY switch interfaces with the optical SAP and connects to the optical media, which may consist of a single or multiple optical sources and photodetectors. Multiple optical sources and photodetectors are supported in the standard for PHY III as well for VLC cell mobility. The PLME controls the PHY switch in order to select a cell. The line going to the optical SAP from the PHY switch is a vector. The number of lines comprising the optical SAP has the dimension of $n \times m$, where 'n' is the number of cells and 'm' is the number of distinct data streams from the PHY. The value of 'm' is three for PHY III. The coordinator or optical sap will service and manage the operation of multiple cells. In this scenario the interference of color channels between neighbor cells must be considered strongly in channel allocation process. If the interference is being experienced from an adjacent light, then hopping can be used to mitigate the interference. Because of the limitation and heterogeneous effect of color channel on different environments, especially intensity modulation, the optical channel should be reused, scheduled efficiently or cooperated with diversity technology. However, with the current issue of specification, it is still an open issue. The limitation of current specification for color channel allocation is shown in Fig. 3. In this scenario, terminal #1 and terminal #2 set up the link connection with cell (1, 1) and cell (1, 2). With the connection location of two terminals, based on the channel allocation process, they can be allocated the same color channel because after exchanging the information of the wavelength quality indication (WQI) list during active and passive scans, the survey quality of the color channel will have the same information. We will overcome this problem by an enhancement color channel allocation based on the performance of SNR and bit-error rate (BER). The proposed mechanism will be presented in detail in the next section.

The main contribution of the paper can be summarized by the following issues:

- Interference model for the optical channel.
- Color channel performance analysis based on SNR.