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Resource allocation for multichannel broadcasting visible light communication

Nam-Tuan Le, Yeong Min Jang*

Department of Electronics engineering, Kookmin University, Seoul, Republic of Korea

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ABSTRACT

Visible light communication (VLC), which offers the possibility of using light sources for both illumination and data communications simultaneously, will be a promising incorporation technique with lighting applications. However, it still remains some challenges especially coverage because of field-of-view limitation. In this paper, we focus on this issue by suggesting a resource allocation scheme for VLC broadcasting system. By using frame synchronization and a network calculus QoS approximation, as well as diversity technology, the proposed VLC architecture and QoS resource allocation for the multichannel-broadcasting MAC (medium access control) protocol can solve the coverage limitation problem and the link switching problem of exhibition service.

1. Introduction

Compare with wired connections, wireless communications suffers from a tightly controlled medium by the lower channel bandwidth. Visible light communication (VLC), which can achieve both illumination and data transmission using visible light, is one issue for this limitation. An increasing number of applications and services use visible light from lighting as a communication medium, especially in indoor applications. As with other wireless technologies, the VLC medium is inherently error prone. Even though the radio may have sufficient channel bandwidth, factors such as multiple-access, signal fading, noise, and interference can significantly lower the effective throughput in wireless networks. VLC, with its field-of-view (FOV) limitation and color band interference, faces many challenges, especially link switching and recovery. In the traditional VLC link switching technique, a bidirectional link is required between an access point (AP) and a terminal, as shown in Fig. 1. When the terminal moves far away from the service AP, the received signal will be decreased in strength. The terminal should try to connect with the neighbor's AP to maintain a continuous data stream. This will require complex processing that involves multiple technologies for functions such as sensing signal strength, target selection, etc.

The current trends in technological development show that digital integration broadcasting networks and diversity will play an important role in future wireless communication and computer network. In the existing digital broadcasting systems, most data are in the form of continuous streams, such as video data or voice data. The links between nodes are considered to be bidirectional, but in broadcasting applications, unidirectional links are employed, which necessitate special treatment by the MAC protocols. For diversity technique, it is one of the powerful techniques that can be applied to wireless communications systems to improve performance over a fading radio channel [1,2]. In this technique, the basic strategy of the diversity issue is repetition and redundancy of transmission information. The receiver gets multiple copies of the same information signal, which are transmitted over two or more communication channels. The signal is transmitted and received through multiple paths, which are supplied with multiple transmitting and receiving antennas. The diversity decisions are made by the receiver independently of the transmitter.

In this paper, we will analyze and propose a new mechanism for QoS multichannel resource management for broadcasting VLC service. The proposed issue is based on the diversity technique for the non-link switching problem and QoS channel allocation. The scenario of our proposed scheme is shown in Fig. 2, which depicts a museum data broadcast VLC system. Visitors can download information on paintings of interest at their convenience. In this scenario, the painting is covered by LEDs with various coverage ratios. There are some challenges in implementing this scenario.

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

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0030-4018/

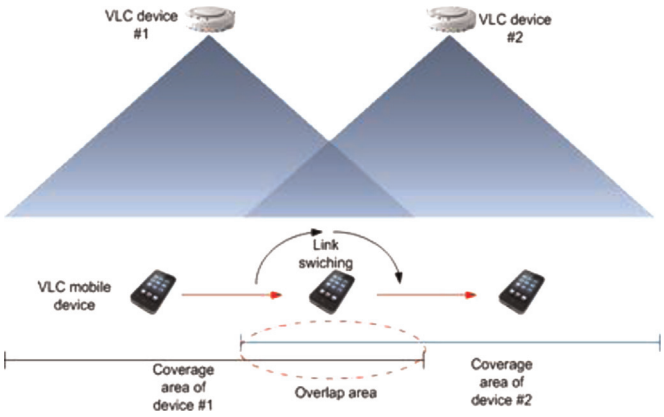

Fig. 1. Link switching scenario.

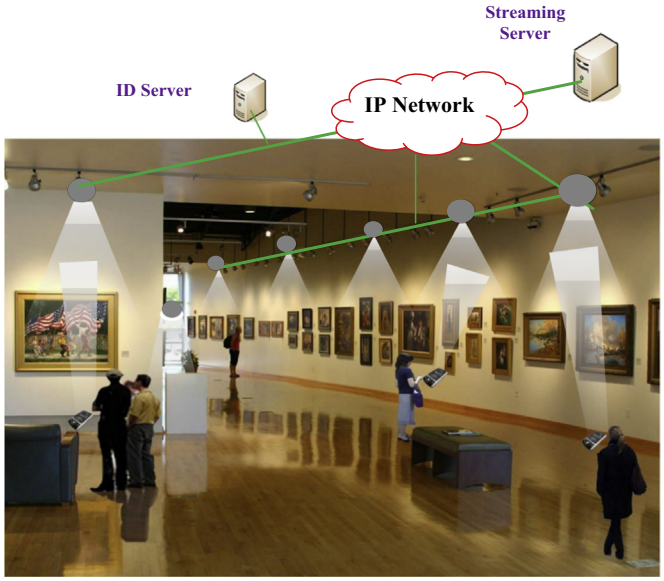

Fig. 2. Scenario for diversity broadcasting VLC.

How can a visitor download information on the painting of interest if his or her location is out of the coverage LED? How can an unexpected movement between two coverage LEDs be handled? These problems can be solved in a simple manner with a bidirectional link with a request-and-reply mechanism. Because of the complexity and the cost of such a system, our proposed system will be based on a broadcasting service. The data information of one painting exhibition will be broadcast by the main coverage area and neighbor LEDs. The visitors can download painting information from the main LED and neighbor LEDs without the limitation of data of interest or a link switching protocol. There is no need for feedback information and replies to be sent from the AP to the terminal. The broadcasting data stream of one specific painting will be broadcast continuously from its LED and neighbor LEDs, after which the terminal joins the common area. It will then receive the signal as part of a diversity scenario. This is also the main reference of our proposed protocol for this paper.

The main contributions of this paper can be summarized as follows:

a. Diversity analysis model for optical channel
b. Multichannel broadcasting based on frame synchronization
c. QoS approximation model for channel allocation
d. Frame structure for diversity broadcasting services
e. Channel allocation scheme for diversity broadcasting services

The structure of the paper is organized as follows. An overview of the VLC system and related studies are presented in Section 2. The details of the proposed multichannel allocation scheme based on QoS approximation and diversity are presented in Section 3. Section 4 describes the analytical evaluation and experimental implementation performance of channel allocation based on the broadcasting service. The concluding remarks on the proposed scheme are presented in Section 5.

2. VLC and related studies

VLC is a new communications technology that uses visible light as the communication medium. An increasing number of applications in, both indoors and outdoors, use visible light from lighting as a communications medium. Research on VLC has been under way for several years, and it is a promising technology for the future. Various modulation techniques [3–7] can be applied for VLC ranging from a low to a high data rate. They can be classified as on–off keying modulation (OOKM), variable pulse-position modulation (VPM), pulse-position modulation (PPM), sub-carrier pulse-position modulation (SC-PPM), sub-carrier frequency shift keying (SC-FSK), sub-carrier phase shift keying (SC-PSK), pulse width modulation (PWM), color shift keying (CSK) and OFDM. Among them, OOKM, VPM, and CSK are frequently used in VLC. Visible light links are commonly classified according to two criteria on the basis of the degree of directionality of the transmitter and the receiver. The communication link relies on the existence of a line-of-sight path between them. The line-of-sight links employ narrow FOV transceivers that must be aimed in order to establish a communication link [8,9], while non-line-of-sight (NLOS) links employ wide FOV transceivers. LOS links rely on a direct path between the transmitter and the receiver for communication, whereas NLOS links usually rely on reflection of light from the ceiling or some other diffusely reflecting surface. An LOS link between two transceivers is important for high data rates [10].

The research on VLC mostly focuses on data rate enhancement, modulation, flicking, color channel interference, and channel allocation [11–14]. For the performance resource enhancement problem, the multiple-input-and-multiple-output (MIMO) [15,16] technique appears to be the most attractive solution to improve the data rate. IEEE 802.15.7 [17] was standardized as a commercial specification in 2011. The IEEE 802.15.7 standard defines a PHY layer and a MAC layer for VLC. The architecture is defined in terms of a number of blocks, called layers, in order to simplify the standard. Each layer is responsible for one part of the standard and offers services to the higher layers. A VLC WPAN device comprises a PHY layer, 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 transfers. 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 applications with multiple light sources and detectors with a 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 a convolutional code and a Reed–Solomon code. Depending on the application requirements, an IEEE 802.15.7 WPAN may operate in one of 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 in range of each another. Apart from these 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 with them. Star networks operate independently of all other star