Virtual Cognitive MAC for Visible Light Communication System

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Abstract

Cognitive Radio technique exploits underutilized licensed spectrums to improve its bandwidth availability. Using CR technology, node is able to adapt its transmission and reception radio parameters including channel frequency dynamically according to local spectrum availability. In visible light communication, due to the limitation and heterogeneous effect of color channel on different environment, the link quality will effect. In this article, new approach for multi-channel MAC for visible light communication, named Virtual cognitive MAC, is proposed to increase the performance of visible light communication system. It can be used in the promising communication technology, VLC, an encouraging green and energy-efficient communication technology. Numerical results show that, with the proposed system, we can reduce the blocking probability and improve the system performance.

Keywords: *visible light communication, multi-channel, cognitive MAC.*

1. Introduction

Visible light communication using a light emitting diode (LED) is a promising technique for simultaneous wireless communications and lighting functions in indoor environments. The advantage of VLC is that it offers communication and illumination simultaneously. LED supplies the benefits of fast switching, long life expectancy, lower cost, and being safe for the human body. For both indoor and outdoor environments, efficient traffic management meets the application of specific requirements for the VLC. Like other communication systems, VLC offers opportunities for different types of users. So efficient resource assignment is an important issue. A traffic management scheme in the network for low call blocking probability scheme must be supported so that traffic from all customers is optimally protected and delivered and does not interfere with traffic from other subscribers.

In radio frequency system, channel is defined by using different frequencies. With visible light communication, the channel is defined by different colors waveband of visible light between the wavelength of 375 nm and 780 nm. Different colors have different wavelengths. The color of channels is changed due to wavelength changes. Multiple optical sources may be used for different color bands, including optical guard channels. Intensity variation is used for each fundamental color LED to produce different colors of the channel. Based on this operation, the color band is classified into N color channels. The value of N depends upon the characteristics of LEDs and photo detectors.

There are different types of modulation techniques, like PAM, PWM, PPM, OOK, and intensity modulation are used in visible light communication. However intensity modulation has the advantage of being particularly easy to implement; the optical output power of the source is simply varied according to the modulating signal. The optical signal thus produced is also easy to detect and the modulating signal is easily recovered from the output of a photodiode. The data is modulated onto an electrical signal which, depending on the details of the electrical system, may be represented by either current or voltage. An optical intensity modulator generates an optical signal with intensity (not amplitude). In an optical transmission with Intensity Modulation/Direct Detection (IM/DD), a DC bias is usually added to the signal to ensure that the signals are all positive. The current multicarrier scheme OFDM is used in visible light communication. In an OFDM system, a high data-rate serial-data stream is split up into a set of low-rate sub-streams. The parallel data transmission offers possibilities for alleviating many of the problems encountered with serial transmission systems, such as inter-symbol interference (ISI) and the need for complex equalizers. The total channel bandwidth is divided into a number of orthogonal frequency channels. Each low-rate sub-stream is modulated on a separate sub-carrier. The complex symbols are then transformed into a time-domain signal via the Inverse Fast Fourier Transform (IFFT). A cyclic prefix (CP) is attached as a guard interval to mitigate the effects of multipath-induced ISI. The length of cyclic prefix (CP) is normally considered to be greater than or equal to the channel length (impulse response time) to ensure the prevention of ISI. The OFDM baseband signal may be used to modulate the LED intensity; for that case, any complex values must be avoided. The generated OFDM signal envelope is bipolar, and optical intensity cannot be negative. Therefore, the LED should be biased before applying the OFDM modulating signal.

In this paper, we propose an efficient and priority-based resource allocation scheme for color channel selection. Scheme is an enhancement of IEEE 802.15.7 MAC specification [1], can be called as virtual cognitive MAC. The remaining of paper is structured as follows. The overview of visible light communication system will be presented in section 2. The proposed channel selection scheme is shown in section 3. Section 4 evaluates the performance of the proposed scheme and the improvement result from simulation. Finally, concluding remarks of the research results and contributions are given in section 5.

2. Visible Light Communication System

The VLC system transmits digital signals by controlling the ON/OFF repetition of LED or the color of transmitted light. There is a difference with RF system, in VLC system; LED plays the role of a transmitter and the PD that can detect the blinking of light plays the role of a receiver. The structure of VLC system is illustrated in Figure 1. The transmitter is composed of power part, data signal part, and control part. The receiver is composed of PD part and data demodulation part. The power part of the transmitter supplies power to the LED drive circuit to provide power for ON/OFF. The data signal part sends the digital signals coming from the outside to the data modulation circuit, which modulates data through the line encoding block, modulation block. The modulated data signals are sent to the LED drive circuit to control the LED transmission. For the receiver, the light signals received through the PD are transmitted to the amplifier block, clock restoration block, and line decoder/demodulation block.

The VLC channel model can be extended from infrared communication system as:

$$\boldsymbol{p_r} = \boldsymbol{p_t}\, H(0)_{LOS} \tag{1}$$

where the received light intensity P_r is determined by the multiplication of the transmitted light intensity P_t and the path loss of the light-wireless communication channel in the LOS environment $H(0)_{LOS}$.

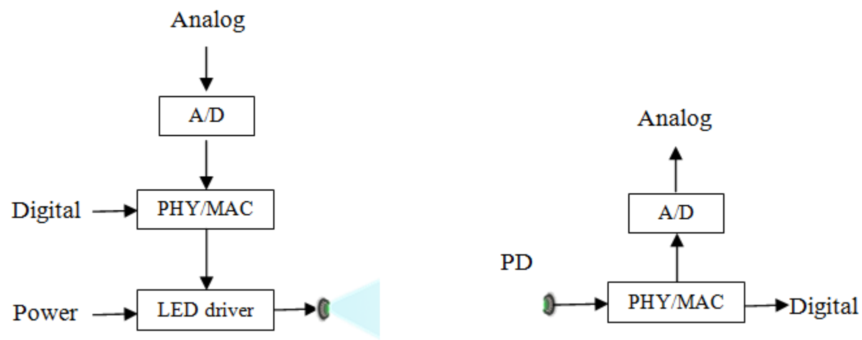

Figure 1. VLC Architecture

3. Proposed Channel Allocation Scheme for MAC Protocol

IEEE 802.15.7 specification defines 7 colors channel for PHY layer in visible light communication. The received power from color channel band will affect directly on demodulation. The output current from receiver photo-detector at the center wavelength 480 nm, 535 nm and 625 nm is shown in Figure 2. The received powers for blue, green and red color channels are not constant. But this variation affects the performance of the system even though receiver expects same performance for each color of channel. SNR is directly proportional to the square of instantaneous received power. SNR variation affects the data rate of the VLC system. SNR also depends upon multipath fading, inter-symbol interference and other noise. Figure 3 shows the SNR for VLC receiver at the center wavelength of different color of channels.

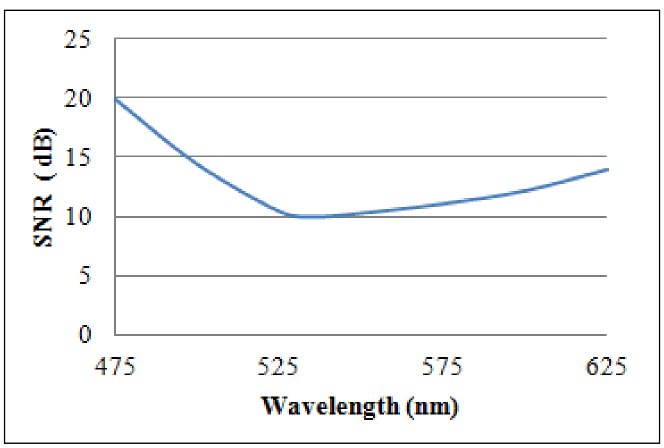

Figure 2. Received SNR vs Wavelength

Our scheme focus on color selection problem for intensity modulation PHY which based on OOK and VPPM modulation. The value of ***phyCurrentChannel*** in PHY header will be set by passive or active scan as flowing flow chart in Figure 3. The channel for scanning process will be set priority as Table I.

Table 1. IFS Configuration

Frequency band		Color	Priority band
380	450	pB	1
450	510	B,BG	2
510	560	G	7
560	600	yG, gY	6
600	650	rO	5
650	710	R	4
710	780	R	3

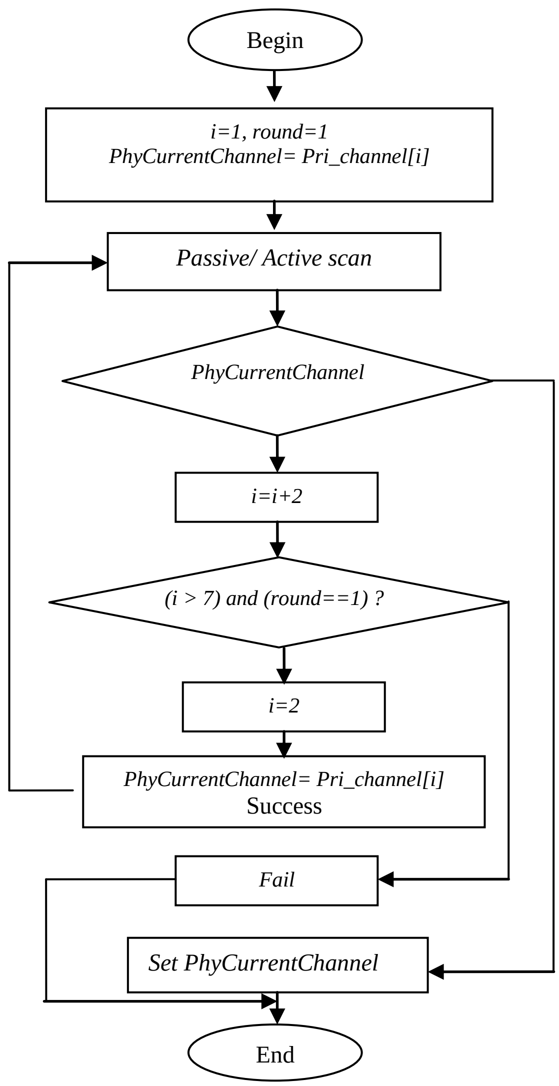

Figure 3. Channel Selection Scheme for MAC Protocol

4. Performance Evaluation

A SNR can express the quality of a communication system. We assume that the transmitter transmits the signal using on-off keying (OOK) modulation technique. Among all modulation techniques for visible light communication link, OOK is the simplest one and it is very easy to implement. In a single receiver, the average signal-to-noise ratio (SNR) is defined as the ratio of the received signal to the aggregated noise and it can be seen that when the shot noise is the dominant noise source, the SNR is proportional to the detector area [3]. The signal component of the signal to noise ratio is measured by:

$$\boldsymbol{s = \mu^2 p_r^2} \tag{2}$$

where P_r is the desired received power. If we considered about multipath fading, the value of P_r can be represented as:

$$p_r = \sum_{i=1}^{\infty} \int_0^T (h_i(t) \otimes X_i(t))dt \tag{3}$$

The received power by inter-symbol interference P_{rISI} is given by:

$$p_{rISI} = \int_T^{\infty} \sum_{i=1}^{L} h_i(t) \otimes X_i(t)\, dt \tag{4}$$

In the our proposed scheme for color channel selection, the channel quality of link will be effected by the neighbor adjacent color channel and background light. The Gaussian noise value of equation (3) and (4) will effected on the performance . From the distribution of SNR with interference [3], we analyze our scheme with a random color noise for channel selection. If two link using same color channel and overlap together in receiver side we assume that all data will be broken.

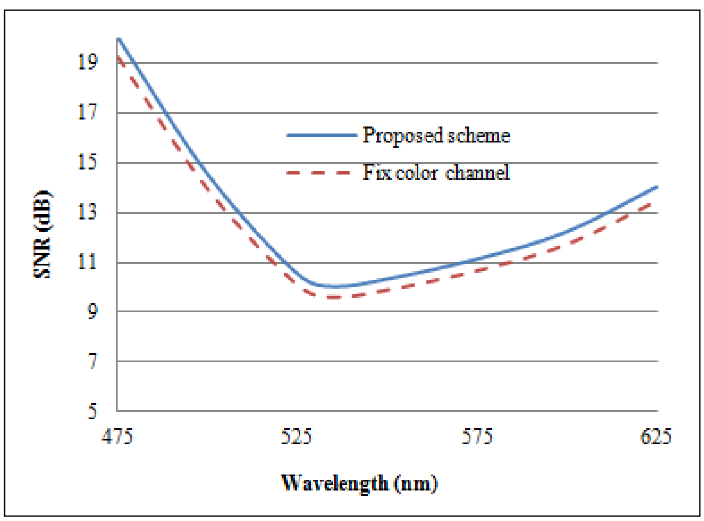

Figure 4. SNR Comparison

5. Conclusions

In this article, we proposed a dynamic color channel allocation for Visible Light Communication. The analysis based on intensity modulation from PHY I, PHY II and PHY III of IEEE 802.15.7 specification.

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