Interference Control Technique through Cooperative Communication in Overlap Region According to FOV in Indoor Visible Light Communication Environment

Doohee Han, Kyujin Lee

Abstract Background/Objectives: Visible light communication must satisfy both lighting and communication performance. When a large number of lights are present in an indoor environment, interference occurs between adjacent LEDs. Since the area where such interference occurs increases according to the illumination angle of the illumination, an interference control technique according to the interference area is needed. However, existing interference control techniques are insufficient to solve the optical interference problem received from adjacent light sources.

Methods/Statistical analysis: In this paper, we study the cooperative communication interference control technique to solve the interference generated by many adjacent light sources in indoor environment and to maintain the illumination performance at the same time. It is also important to consider the performance of the light due to the nature of visible light communication. If the FOV is widened by widening the irradiation angle θ ***for the performance of such illumination, the overlapping area between adjacent LEDs becomes wider, resulting in interference and degraded communication performance. To remedy this problem,we propose an interference control technique to decide whether to perform interference cancellation or cooperative communication according to the overlap region according to FOV.***

Findings: Conventional interference control systems can not properly eliminate interference in the maximum overlapping region. However, the proposed system solves this problem through cooperative communication. Through the proposed system, the interference between adjacent LEDs was solved even at the maximum angle of FOV of the illumination and the performance of the communication system was satisfied.

Improvements/Applications: System complexity increases compared to existing systems. Future studies will need to improve this complexity.

Keywords: Optical wireless communication, Visible light communication, interference model, Cooperation communication, Interference control

I. INTRODUCTION

In the era of IoT convergence technology, the fourth industrial revolution, the importance of smart convergence technology is increasing. Visible light communication, which has been attracting attention as a next generation communication technology, is under research for utilization in various fields with the lighting-IT new fusion technology due to the rapid development of LEDs. Because visible light communication uses lighting infrastructure, it is easy to construct a wireless network environment and can be built at low cost, which is a highly utilized technology. In addition, since LEDs with high-speed response characteristics are used, the visible light wavelength is used without using RF. Therefore, frequency resource authorization and authentication are not required, a wide visible light bandwidth can be used without frequency interference, Excellent in function. In addition, high-speed multimedia data transmission is possible, and it is considered as next generation wireless communication technology to replace RF. [1-2] The development of technology for visible light communication started with the development of LED devices and the publication of a paper about visible light communication at Keio University in Japan in 2000. As the LED lighting infrastructure has become widespread and the interest of visible light communication has increased, VLCC, aoptical wireless communication standardization consortium, was formed in Japan. Currently, many universities, research institutes and companies in Japan are conducting standardization research in VLCC. Japan is the first to start research on visible light communication, and has been performing in various fusion technology fields. In addition to Matsushita Electric, we have studied location information detection technique for position tracking in visibility optical channel modeling and visible light communication in indoor environment, and received PD data from multiple LEDs in parallel for high speed visible light communication, Thereare various studies to solve the problem of transmission speed and reception distance.[3]Since such visible light communication provides illumination function and communication at the same time, a control technique that satisfies the performance of both sides is needed.In order to reach a wide range of illumination, it is necessary to broaden the irradiation angle of light. However, in an indoor environment, multiple lights act as interference in the

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communication system. The range of the light source is widened as the irradiation angle of light is widened. However, this causes communication interference between adjacent light sources and deteriorates the performance of the system. In this paper, we analyze the light overlapping region according to the light irradiation angle between adjacent light sources in the indoor environment, and study the technique to solve the interference generated in the overlapping region. The FOV varies depending on the angle of the adjacent light source. At this time, when the optical overlap region according to the FOV is less than 30%, communication is performed using the existing interference cancellation technique. However, if the light overlapping region exceeds 50% and more than half of the light sources overlap, severe interference will occur. In the section where the light overlapping region is 30-50%, cooperative communication is performed between adjacent LEDs and one channel. When the light overlapping region exceeds 50%, cooperative communication is performed in two channels to suppress the occurrence of interference. Through the proposed method, it is possible to improve the performance of the entire system by controlling the generated interference while maintaining the maximum illumination performance of the adjacent LED light sources.[4-6]

II. PROCEDURE FOR PAPER SUBMISSION

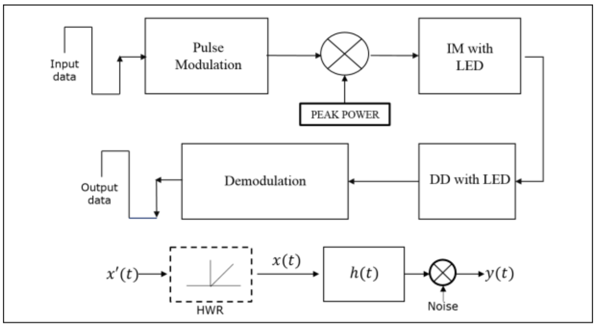

Fig. 1.VLC system model

The system is assumed to be a line of sight (LOS) link. Optical wireless system structure is shown Fig. 1. IM / DD modulation is generally used for visible light communication. The intensity modulation uses the LED's bias current to vary, and the photodetector produces a photocurrent proportional to the light output of the received signal. Equation 1 shows a visible light communication channel model.The transmission waveform is emitted to the light wavelength and is received via the PD. The noise model is additive white gaussian noise (AWGN). [7-8].

$$\alpha S(t) * G(t) + N(t) \tag{1}$$

In Equation 1, the symbol * denotes convolution. G (t) means the system impulse response. N (t) means AWGN.

2.1. Light Receiving Efficiency in LOS Environment

InVLC system, when a signal is transmitted from a transmitter to a receiver, it can be divided into a reception signal by the direct light and a reception signal by the reflection light. Here, the reception signal by direct light is an environment in which there is no obstacle obstructing the light between the LED illumination and the receiving PD. A reception signal by reflected light refers to an environment in which light is reflected and received by an obstacle such as a wall, a window, or a table existing in a room. The signal strengths of the above two reception environments considering the optical wireless channel environment are as follows.In the case of a received signal by direct light, the average optical signal intensity emitted by the LED light is given by:

$$p_t = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} X(t)\,dt \tag{2}$$

The average received optical power is expressed as a product operation as follows.

$$P_r = H(0)P_t \tag{3}$$

In the optical wireless link, the channel gain (Channel DC gain) is $H(0)$ and is defined as follows.

$$H(0) = \begin{cases} \frac{(m+1)A}{2\pi d^2} cos^m(\varphi)\, T_s(\psi)\, g(\psi)\, \cos(\psi)\,, 0 \le \psi \le \psi_c \\ 0, \psi \le \psi_c \end{cases} \tag{4}$$

Where $T_s(\psi)$ is the optical filter gain and FOV (field of view) of the receiving PD. ψ_c Denotes the physical area detected by the PD, and $d$denotes the distance between the transceivers.

In the case of the environment of the received optical signal intensity according to the reflected light, the average optical signal intensity and channel gain radiated by the LED illumination are the same as in the case of direct light. However, in the case of received optical signal strength, both direct and reflected optical signals must be considered. Therefore, it can be expressed as follows.

$$P_r = \sum^{\le D_r}\{P_t H_d(0) + \int P_t\, dH_{ref}(0)\} \tag{5}$$

In the optical wireless link, the channel gain due to the first reflection (Channel DC gain) is $dH_{ref}(0)$ and is defined as follows.

$$dH_{ref}(0) = \begin{cases} \frac{(m+1)A}{2\pi^2 D_1^2 D_2^2} \rho dA cos^m(\phi)\cos(\alpha)\cos(\beta)\, T_s(\psi)\, g(\psi)\cos(\psi)\,, \\ \quad 0 \le \psi \le \psi_c \\ \quad 0, \psi \ge \psi_c \end{cases} \tag{6}$$

Where D_1 is the distance between the transmitting end and the receiving end, and D_2 is the distance between the receiving end and the reflecting point. $\rho$is the reflection coefficient, dA is the reflection area of the room, ϕ is the radiation angle of the reflection point, β is the radiation angle of the receiving end, and ψ is the incident angle.

At any point receiving an optical signal, the illumination includes LOS (Line of Sight) emitted directly from the LED as well as taking into account reflection from the object or wall of the room. Such LOS has a form in which characteristics such as direct light and reflected light are mixed. And the channel response characteristics according to LOS are modeled by the Dirac distribution. If the channel frequency response is represented by an exponential function in terms of optical power, it is as follows.

$$H(f) = \sum_i \eta LOS\, i^{\exp(-j2\pi f \Delta_{\tau LOSi})} + \eta DIFF \frac{\exp(-j2\pi f \Delta_{\tau DIFF})}{1 + jf/f_0}$$

(7)

Where

$\eta LOSi$,ηDIF denotes the channel gain of the LOS and

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the diffuse signal, $\Delta_{\tau LOS}\Delta_{\tau DI}$ denotes the LOS and diffuse signal delay.

III. PROPOSED SYSTEM MODEL

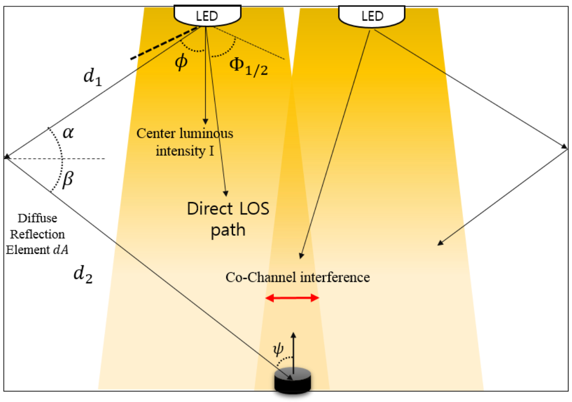

Fig. 2. Interference model

Fig. 2. shows the proposed interference system model.A reception signal by reflected light refers to an environment in which light is reflected and received by an obstacle such as a wall, a window, or a table existing in a room. Since the indoor environment using the LED lighting infrastructure uses a plurality of light sources, interference occurs between the LEDs. In addition, the multi-path signal components due to the path difference between a plurality of light sources and receivers act as interference between each other, which causes ISI and CCI to deteriorate system performance. In a channel with multiple paths, the received signal can be expressed in a form in which signals passing through different paths are added. The different sizes and time delays of these multipaths lead to a change in the magnitude and phase of the spreading sequence at the time of restoration, thereby distorting the orthogonality of the spreading sequence. Therefore, in the environment where there are a plurality of light sources and a plurality of users rather than one light source, a light source from a plurality of transmitters generates ISI and CCI at the receiver. This results in performance and QoS degradation of the visible light communication system.[9-10]

2.1. *Collaborative communication technique according to interference area*

The proposed system model is shown in Fig. 3. In the indoor environment, multiple lights are located and adjacent LEDs cause interference. The light reaching range of each LED causing such interference is called aoverlap area.

In this paper, according to the area FOV of the irradiation angle θof the change in illumination of the received power, and ring sectors to the overlap region to cause an interference of up to 50%. When the receiver is located in the overlap region, to apply an interference cancellation scheme in accordance with the range of the overlap region the sector, is determined journal influence of the interference by switching to the cooperative communication. If the overlap area according to the FOV is less than 30%, communication is performed using the existing interference cancellation technique. However, interference control through interference cancellation techniques is difficult when the overlapping area reaches 50% level. At the center of the overlap area, the received power received by both LEDs is almost the same, so interference is intensified. Therefore, if the overlapping area is 50% or more, the switch to the cooperative communication mode, and the adjacent transmitted by assigning the channel between the LED in cooperative communication channel.

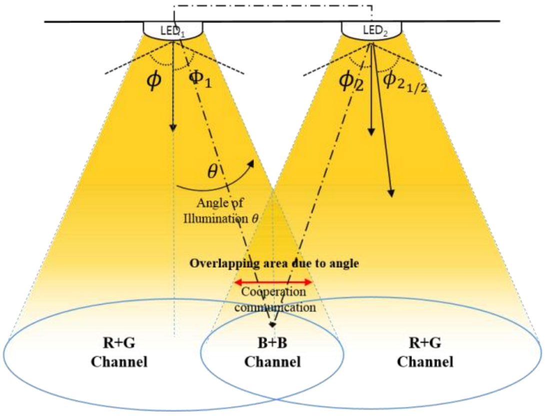

Fig. 3, Proposed System model

Fig.5. shows the flow chart of the system. The FOV is calculated according to the illumination angle of the illumination, and the overlap area is determined through the calculation. First, the existing interference cancellation method is applied at the level of 30% of the overlap area. Channel cooperative communication when the overlap area is 50%, and 2-channel cooperative communication when the overlap area is 50% or more. For example, in the overlap region 40%, B channels among adjacent LED channels are cooperatively communicated with each other, and R + G channels are used other than overlapping regions. When the overlapping area exceeds 50%, R + G is used as the cooperative communication channel, and the B channel is used outside the overlapping area. Fig. 4.shows the transmission / reception structure of the proposed system.

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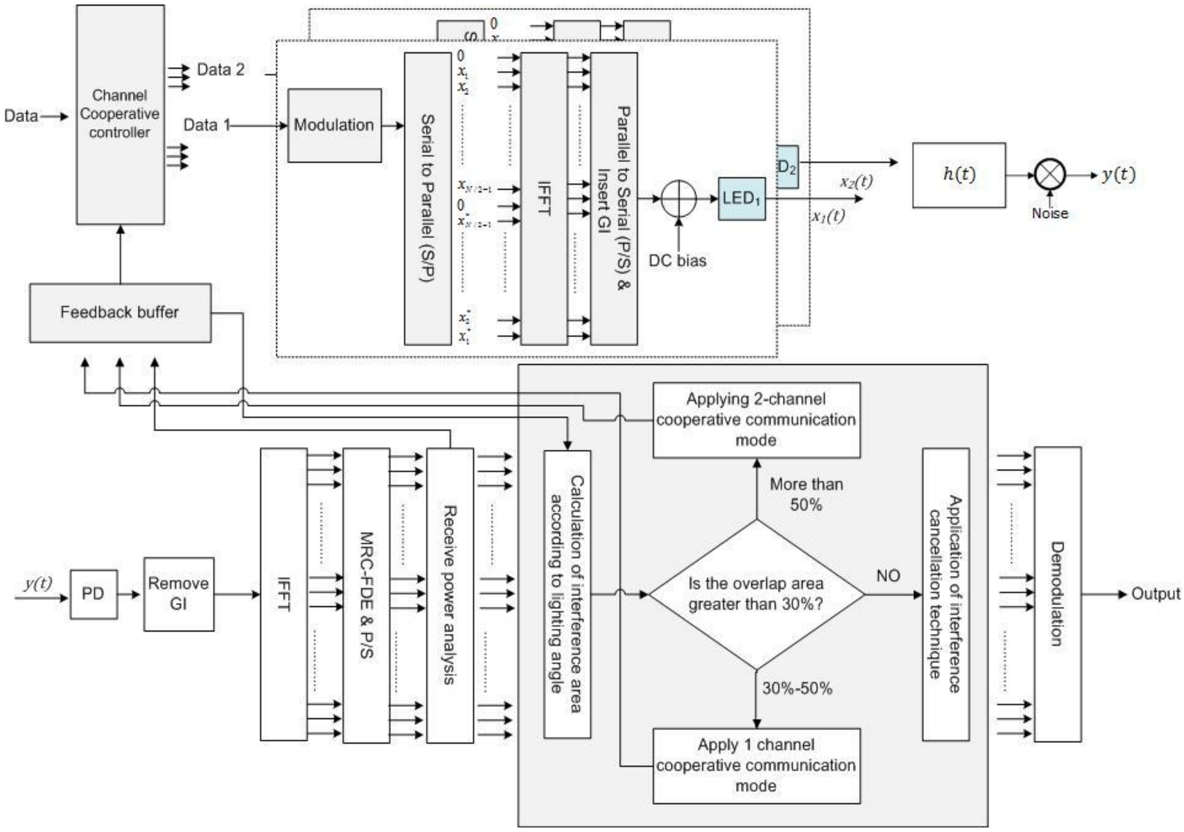

Fig. 4Transmitter and receiver structure

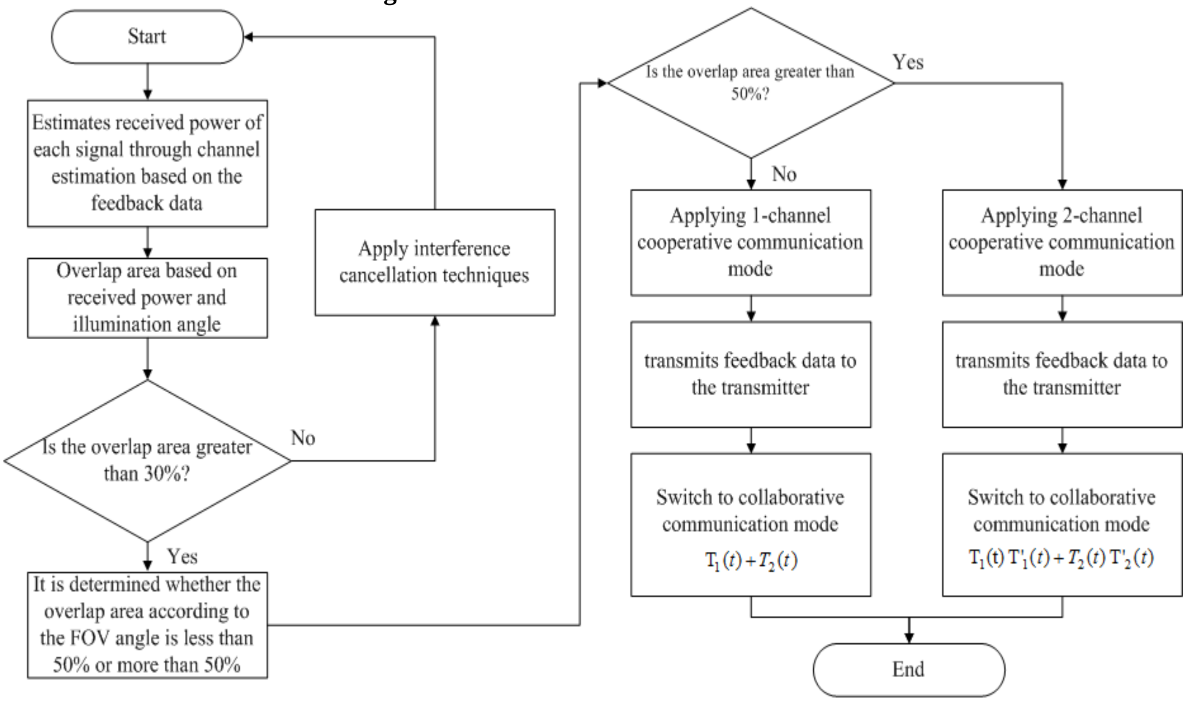

Fig. 5.Proposed system flowchart

IV. SIMULATION RESULTS

In the indoor environment, the conventional method is compared with the transmission through cooperative communication in the interference space between two adjacent white LEDs. IM-DD modulation is used on the AWGN channel, and the interference overlap range is 30%.

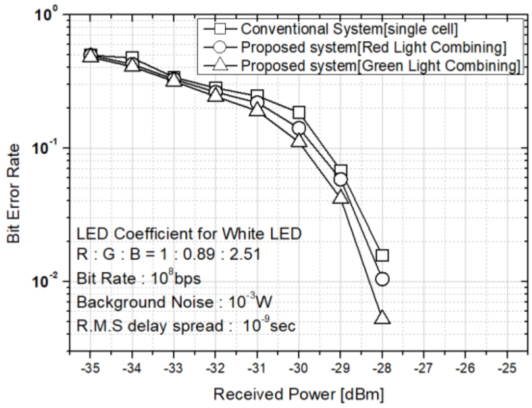

Fig. 6.BER performance according to cooperative communication in overlapping area

Fig.6. shows the performance of the proposed system when the overlapping interval between two adjacent LEDs is 30%.When the interference area in the overlapping region exceeds 30%, the cooperative communication mode is switched. Figure 7 compares the reception performance of R + R channel and G + G channel through the reception performance and cooperative communication in the conventional one LED. As shown in the figure, BER performance increases when switching to cooperative communication as compared with the existing system. In addition, when switching to the cooperative communication mode, there is no need to add interference cancellation technique used in the existing system, so the complexity of the system is improved and the hull performance is increased.

V. CONCLUSION

In this paper, we study the cooperative communication interference control technique to solve the interference generated by many adjacent light sources in indoor environment and to maintain the illumination performance at the same time. It is also important to consider the performance of the light due to the nature of visible light communication. If the FOV is widened by widening the irradiation angle for the performance of such illumination, the overlapping area between adjacent LEDs becomes wider, resulting in interference and degraded communication performance. To remedy this problem, we propose an interference control technique to decide whether to perform interference cancellation or cooperative communication according to the overlap region according to FOV. Through the proposed system, the interference between adjacent LEDs was solved even at the maximum angle of FOV of the illumination and the performance of the communication system was satisfied. However, the complexity of the system increases compared to the existing system. Future studies will need to improve this complexity.

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REFERENCES

1. A. Z. Suriza, SharminAkter, M. Shahnan, Preliminary analysis of dimming property for visible light communication. IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), 1-5, 2017
2. Zhen Feng, CailiGuo, ZabihGhassemlooy, Yang Yang, The Spatial Dimming Scheme for the MU-MIMO-OFDM VLC System. IEEE Photonics Journal Vol.10 Issue. 5 Article Sequence Number: 7907013, 2018
3. Ezra Ip, Joseph M. Kahn, Fellow, Power spectra of return-to-zero optical signals Journal of Light wave technology, Vol 24, No. 3, 2006
4. Kyujin Lee, Dimming Level Control Technique for Lighting / Communication Functions in Visible Light Communication Systems Journal of Convergence for Information Technology Vol. 8 No.5. 153-158, 2018
5. Kim, K., Lee, K., Lee, K.: 'An inter-lighting interference cancellation scheme for MISOVLC systems', Int. J. Electron., 2017
6. M.G. Craford, "LEDs challenge the incandescents", IEEE Circuitsand Devices, pp. 24-29, September 1992.
7. Sihua Shao, Abdallah Khreishah, Issa Khalil, Joint link scheduling and brightness control for greening VLC-based indoor access networks IEEE/OSA Journal of Optical Communications and Networking Vol. 8, Issue: 3. 148, 2016
8. Kyuntak Kim, Kyujin Lee "Performance Evaluation and Analysis of Zero Reduction Codes for Effective Dimming Control in Optical Wireless Communications using LED Lightings" Journal of Convergence for Information Technology Vol. 7 No.3 pp.97-103, 2017
9. Gyun-TakKim Doo-Hee Han Kye-San Lee Kyu-Jin Lee , Analysis Performance of VLC System according to the Transmission Distance and Angle of Incidence. Journal of Convergence for Information Technology, Vol. 4, No. 4. 37-42, 2014
10. Hyo-duck Seo Kyu-Jin Lee, Efficient Data Transmission in LED-based Visible Light Communication Using Variable RGB Interleaving scheme, Journal of Convergence for Information Technology, vol.7 no.6, 167-172, 2017

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