Analysis and Research Direction of VLC Interference Environment in IoT Sensor Network

Doohee Han, Kyujin Lee

Abstract Background/Objectives: visible light communication is very attractive for use as a convergence technology in the field of IOT sensor network which is a short distance communication. In a situation where the lighting infrastructure is already in place, it is a very suitable technology for creating a network group between a plurality of lights and IOT devices. However, the existing visible light communication environment is insufficient to solve the light interference problem that is received from other adjacent light sources in the environment where a plurality of IoT devices exist. Due to the nature of visible light, strong intermittent interference with strong adjacent light sources must be addressed.

Methods/Statistical analysis: In this paper, we assume a rectangular parallelepiped room, illuminate the ceiling and wall of the transmitter LED, and derive a communication channel model in a fixed height environment considering the height of the desk. We propose an interference model between multiple IOT devices and indirect lighting and propose a research method to solve it.

Findings: Since the IoT environment communicates with many devices at the same time, interference due to indirect lighting in such environments greatly degrades network performance. In order to solve these problems, it is necessary to study the interference model and study the interference cancellation technique suitable for the interference scenario. However, if the intensity of the adjacent light source is very strong, it is difficult to appropriately apply the interference cancellation technique. In future work, we need to analyze and analyze the interference cancellation techniques that are currently being studied and find solutions that can solve problems when the power of indirect illumination is strong.

Improvements/Applications: It is necessary to analyze interference scenarios and cancellation techniques that have been studied so far and to find interference cancellation models suitable for sensor networks.

Keywords: Optical wireless communication, Visible light communication, interference model, Iot sensor network, IoT

I. INTRODUCTION

Recently, IoT technology is attracting attention due to convergence technology and development of smart devices. Visible light communication is the next generation wireless communication technology because of fusion of communication and illumination.The wireless network environment can be easily constructed using the lighting infrastructure, and active research is underway.[1] Such visible light communication is very attractive for use as a convergence technology in the field of IOT sensor network which is a short distance communication. In a situation where the lighting infrastructure is already in place, it is a very suitable technology for creating a network group between a plurality of lights and IOT devices. In addition, active research is underway because many devices can be used indoors without interference from electromagnetic waves. However, the existing visible light communication environment is insufficient to solve the light interference problem that is received from other adjacent light sources in the environment where a plurality of IoT devices exist. Due to the nature of visible light, strong intermittent interference with strong adjacent light sources must be addressed.

In order to perform communication, it is necessary to investigate the characteristics of the channel that is the information channel. In the case of direct lighting where the illuminant directly illuminates the subject in the indoor environment, the communication channel research has been conducted to some extent. However, in the case of the indirect lighting using the reflected light by illuminating the wall or the ceiling, I did. Indirect illumination has been used in recent years because of its low luminous intensity due to the same characteristics of illumination distribution. In the aspect of communication channel, there is no direct wave (LOS) between the transmitter (LED) and the receiver (PD) The study of channel and indirect lighting interference is needed. In this paper, we assume a rectangular parallelepiped room, illuminate the ceiling and wall of the transmitter LED, and derive a communication channel model in a fixed height environment considering the height of the desk. We propose an interference model between multiple IOT devices and indirect lighting and propose a research method to solve it.[2-3]

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II. SYSTEM MODEL

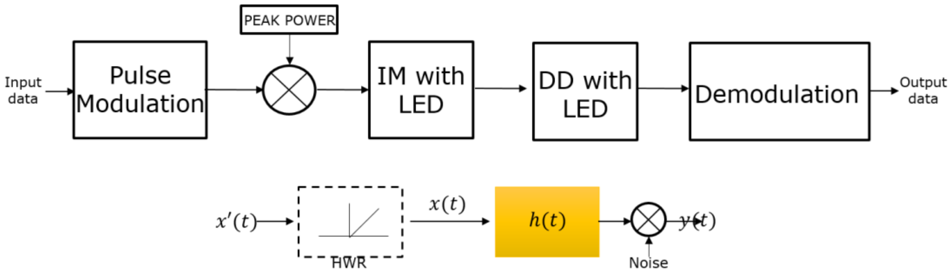

Figure 1. VLC system model

Optical wireless system structure is shown Figure 1. In a VLC system, the received signal appears as reflected light source interference and transmitted signals. The interference signal consists of reflected light and interference light due to another light source. Therefore, the power of the signal received by the receiver is as follows:

$$\mathrm{n}_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}X(t)\,d \qquad (1)$$

The average optical power received by the receiver is given by:

$$(0)P_t \qquad (2)$$

The channel path is assumed to be a LOS (Line of Sight) environment, and it is assumed that there is no obstacle in the communication line.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. At the transmitter, instantaneous optical power consisting of LED visible light wavelength is transmitted. In the PD, optical power proportional to the detected instantaneous power is received.The noise model is AWGN (additive white gaussian noise). [5-6].

$$\alpha S(t) * G(t) + N(t) \qquad (3)$$

The symbol * denotes convolution. G (t) means the system impulse response. N (t) means AWGN.

2.1. *Characteristics of communication channel in indoor rectangular environment*

The visible light communication environment in the room is an optimal space because it can be hardly influenced by outdoor light, and the space where people live or live is mostly a shape of a hexahedron. Indirect lighting techniques are also being used as part of emotional lighting that enriches human life. Indirect lighting refers to lighting a wall or ceiling with light reflected thereon, rather than directly illuminating the subject. Since the light is reflected more than once, the illuminance is uniform, and there is no glare or shade.Visible light communication starts when the data that has undergone electrical signal processing in the transmitter module is changed from LED to optical signal. Then, the photon particles starting from the LED move linearly in the room and then move to the receiving part (PD), and the optical signal is changed into the electric signal, so that the communication is completed by the decoding process in the receiving module. The characteristics of the photon moving in the room is the visible light communication channel model. A photon reflected by reaching a wall, ceiling, or floor changes its direction, its energy is reduced, and its energy is reduced by the distance it travels, to the square of the distance. Also, since the photodiodes are photographed around every corner of the room, there is a characteristic that arrives with a time difference.[7]

$$\bar{\tau} = \frac{\sum_j e_j^2\tau_j}{\sum_j e_j^2} = \frac{\sum_j P(\tau_j)\tau_j}{\sum_j P(\tau_j)} \qquad (4)$$

$$\sigma_\tau = \sqrt{\tau^2 - (\tau)^2} \qquad (5)$$

$$\tau^2 = \frac{\sum_j e_j^2\tau^2{}_j}{\sum_j e_j^2} = \frac{\sum_j P(\tau_j)\tau_j^2}{\sum_j P(\tau_j)} \qquad (6)$$

$$B_c = \frac{1}{\alpha\sigma_\tau} \qquad (7)$$

The delay spread by multipath is expressed as Mean Excess Delay , rms delay spread , Mean Square Delay τ. The average excess delay is averaged by multiplying the signal power of the multipath and the delay time, and the rms delay spread is an indicator of how spread the signal is. The coherence bandwidth, which is not affected by the selective frequency fading, is calculated as shown in Equation (7). Assuming 50% frequency correlation, is 5, and is 50 assuming 90% correlation.[8-10]

III. MATH

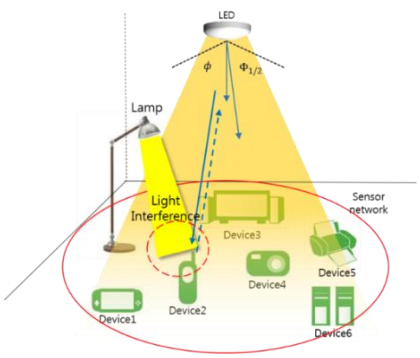

Figure 2. Iot network interference scenario

Figure 2 shows the proposed system model. In the IoT sensor network environment, a plurality of devices exchange sensor information with each other and exchange information with a hub network. In the environment of Figure 2, which consists of visible light communication, Device 2,

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which communicates with the central hub, is subject to severe optical interference by Lamp, another light source in close proximity. If the size of the optical interference is very large, data close to the shadowing phenomenon occurs and it becomes difficult to perform communication properly.In addition, the problem becomes more serious when it is necessary to support bidirectional communication between devices. Optical signals from smaller IoT devices are more susceptible to the main transmit light and indirect light sources, making normal communication impossible. In addition, sunlight coming in from a window into the room acts as a powerful source of interference. In order to construct a sensor network in the presence of such a large number of interference, interference cancellation techniques must be studied.

In the next section, we analyze the interference scenarios and analyze the interference channel environment by analyzing the general interference model.

3.1. Interference model based on indirect lighting

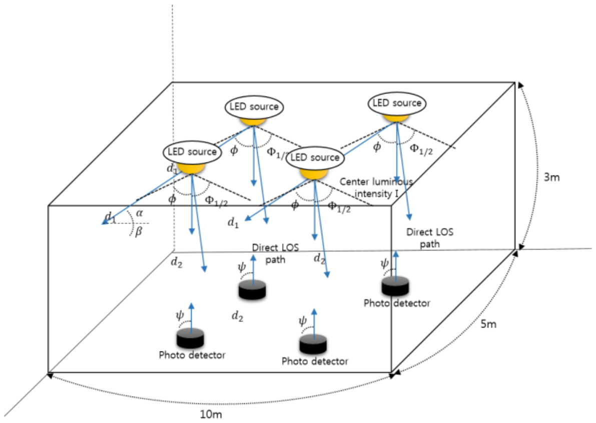

Figure 3. Indirect light source interference model design

In this paper, we assume an indoor environment of 10m, 5m, and 5m as shown in Fig. The LED is indirectly illuminated by directing the light toward the ceiling by placing four LEDs in the central part 30 cm high from the ceiling. The photodiodes were selected as interference models by selecting 10 points 10cm high from the bottom. The parameters are shown in Table 1. The photon starting from the LED starts toward the ceiling point, separated by a 1 mm resolution grid, reflected on the ceiling and moved to the wall or floor. In the indoor environment, when the photon diode reaches the photodiode, the photon diode is changed into a current signal to be converted into an electrical characteristic and used as a communication signal. The light not reaching the photodiode is attenuated in the room and then extinguished. The light emitted from the LED decreases in size in the form of a cosine function as it moves away from the center.

As a result of the analysis of the interference model, the size of the received signal is large at the center of the room where the LED is located and becomes smaller as it goes to the corner. On the other hand, the mean excess delay is small in the central portion and increases in size toward the edge. This is because the center portion of the signal is received with a relatively small delay time, and the corners of the room are opposite to each other.

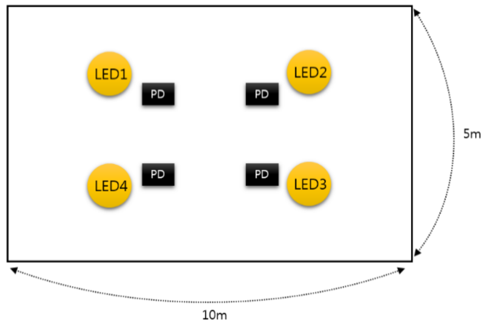

Figure 4. Indirect light source interference model floor plan

The RMS delay spread is the degree of spread of the signal, which decreases in size from the center to the edge of the room. Indoor interference model channel analysis results show that the characteristics of the communication channel vary depending on the location, such as the received signal size, Rms delay spread, average excess delay, and coherence bandwidth. Since light is scattered due to the nature of indirect lighting, there are many shadow areas due to interference from the viewpoint of communication channel. As a result, the energy difference ratio of the maximum signal energy receiving point and the minimum signal energy receiving area reaches up to 80%.

Table 1: Initial Set of features used for the experimentation

Parameters	Values
Size of space	10m * 5m * 3m
LED out power	10W
LED position	x, y, 2m
PD position	x, y, 1m
PD size	0.5cm
Field of View	70°

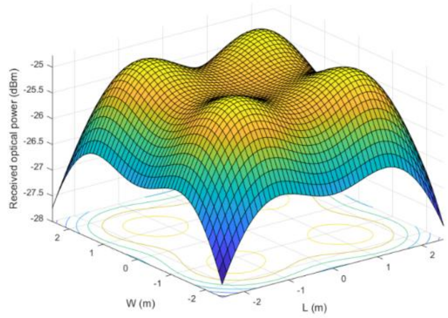

Figure 5. Received signal strength for 4-LEDseach position

Figure 5 shows the signal power received at each PD. It can be seen that the channel environment is different for each position when there are a plurality of light sources. In order to solve the interference due to the indirect light, interference cancellation techniques used in conventional wireless communication technologies have been introduced. However, it is difficult to accurately

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separate the interference signals differently from RF signals due to the characteristics of visible light communication.

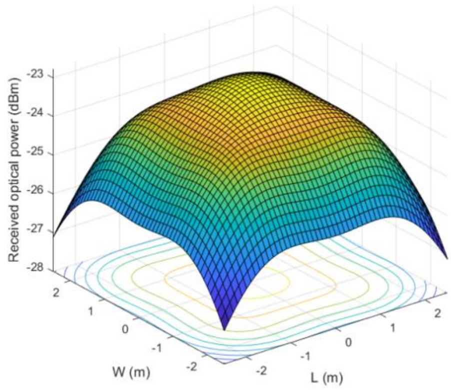

Figure 6. Received signal strength for 5-LEDs each position

Figure 6 shows an environment with additional LEDs in the center in the four LED interference model. When there are five LEDs, it is confirmed that the receiving power of the LED located at the center is the strongest, and the receiving powers of the four LEDs at the other corner are superimposed. In such an environment, the five LEDs would exceed the interference overlap region by more than 50%, and it would be impossible to remove the signal of each LED through the interference cancellation technique. Accordingly, new types of interference cancellation techniques must be introduced by diversifying the interference model and analyzing range data that affect location-based interference.

IV. CONCLUSION

In this paper, we analyze the environment caused by the light source interference in the visible light communication IoT sensor network environment and examine the optical channel model through the indirect light source scenario. Due to the nature of visible light communication, the problem caused by optical interference is serious. In this paper, we examine the phenomenon and suggest the necessity of research to solve the interference phenomenon caused by indirect illumination. Since the IoT environment communicates with many devices at the same time, interference due to indirect lighting in such environments greatly degrades network performance. In order to solve these problems, it is necessary to study the interference model and study the interference cancellation technique suitable for the interference scenario. However, if the intensity of the adjacent light source is very strong, it is difficult to appropriately apply the interference cancellation technique. In future work, we need to analyze and analyze the interference cancellation techniques that are currently being studied and find solutions that can solve problems when the power of indirect illumination is strong.

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REFERENCES

1. Kim, K., Lee, K., Lee, K.: 'An inter-lighting interference cancellation scheme for MISOVLC systems', Int. J. Electron., 2017
2. Zhen Che, Junbin Fang, Zoe Lin Jiang, Xiaolong Yu , Guikai Xi, Zhe Chen,A physical-layer secure coding schcme for visible light communication based on polar codes, IEEE Conferences, 1-2. 2017
3. 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
4. Ezra Ip, Joseph M. Kahn, Fellow, Power spectra of return-to-zero optical signals Journal of Light wave technology, Vol 24, No. 3, 2006
5. M.G. Craford, "LEDs challenge the incandescents", IEEE Circuitsand Devices, pp. 24-29, September 1992.
6. F. Delgado, I. Quintana, J. Rufo, J.A. Rabadan, Crisanto Quintana, R. Perez-Jimenez Design and Implementation of an Ethernet-VLC Interface for Broadcast Transmissions,IEEE Communications Letters Vol. 14, Issue: 12,pp. 1089 – 1091, 2010
7. 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
8. 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
9. 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
10. Gyun-Tak Kim 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

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