Interference and Cancellation Issues for an Indoor VLC Network

Himani Sharma and Rakesh Kumar Jha

Abstract With the high escalating demands of the user for uploading or downloading the data, voice call or sending a text, high speed is required with low latency. This requires larger bandwidth and vast frequency spectrum range. Light Fidelity (Li-Fi) is such a technology which caters to achieve high rising demands of the users thereby providing high quality of service (QoS) and quality of experience (QoE). In Li-Fi, the visible light is used for illumination as well as communication. In Li-Fi, data is transferred from the VLC apex points and received by the user cell phones. Li-Fi is a short range communication link formed with the VLC access point for data transmission and user for its reception. In order to fulfill the desired services, light will be emitted and transferred to the desired demanding users. This causes interference and the desired user may or may not get the light beam signals due to interference. The purpose of the proposal is to reduce the interference level occurred due to the light emitted by the array of LED when the demands of the user rise for an indoor VLC environment. Such interferences can be mitigated with the help of some SIC technique. This paper sheds light on the increase in the interference level and how it impacts the overall system performance rate. This is a next step toward 6G technology.

Keywords Light-fidelity (Li-Fi) · Visible light communication (VLC) · Light emitting diodes (LED) · Successive light interference cancellation (SIC)

1 Introduction

With the massive increase in the usage of LED apex points for illumination and new multimedia applications, the rise in the demand for high speed data rate is growing at fast pace. The sprint in the demand for high speed users, good QoS and QoE is escalating every now and then. Users need the required services for accessing online applications, uploading, downloading, chatting voice call, etc. Li-Fi or VLC

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V. V. S. S. S. Chakravarthy et al. (eds.), *Advances in Signal Processing, Embedded Systems and IoT*, Lecture Notes in Electrical Engineering 992,
https://doi.org/10.1007/978-981-19-8865-3_1

is such a potent at hand in the wireless communication era. Thus, Li-Fi technology which is a short range optical wireless communication link formed between the LED which emits light by the light emitting diodes (LED) and the user at the receiving end where the photodiode converts the changes occurred in the received light into the electric current which is further used for the recovery of the data stream. Li-Fi plays an eminent role in the wireless industry. This illuminating LED which is fitted at every household is used to emit light signal (transmitting source), and the photodiode (receptor) is used to detect the signal and demodulate it into its original signal with the help of optical-to-electrical convertor (OEC). Li-Fi satisfies the user with high data rate requirements and providing safe and secure data transmission and reception. Li-Fi has attracted the attention of both the researchers and the industry due to its fast acceptance in the market.

Li-Fi or VLC is an amalgamation of illumination and communication simultaneously over the line-of-sight (LoS) link. Li-Fi provides the user with continuous or uninterrupted connectivity services because it exhibits large bandwidth. Li-Fi uses visible light for transmission and possesses high bandwidth for indoor area. The LEDs are cost-efficient and highly durable. LEDs are highly energy-efficient, reliable and easy to install. They have faster response. The quality of service improves and this enables high priority applications to run efficiently with lower latency rate. Various other factors such as channel gain must be considered to provide the signals according to the demand of the user. The users enjoy high data rate services with less time delay. If QoS is good, the quality of experience (QoE) automatically becomes better. Better the QoS, better the QoE experienced by the users.

When the user urges for the services, the light beam is concentrated to the desired user based on its demand. LEDs possess no security threat to human life. It is a highly secured scheme. It is highly durable and consumes low power. Therefore, much power is saved. The major threat to this green communication network is interference from the neighboring LED which adversely affects the whole system performance rate. Thus, some energy-efficient technique is required in order to reduce this interference effect which will lead to high QoS and QoE. Our proposal work is based on the mitigating the interferences and boosting up the overall system performance rate of the system.

2 Research Proposal

Contributions: The research proposal aims at designing of an optimal energy-efficient architecture for high quality of communication with high speed user data rate and reduced complexity as depicted in Fig 1. Various modeling techniques are represented in [1], for indoor, outdoor, underwater and underground environment. Research is carried out for designing of an energy-efficient system, thereby reducing excess power consumption. In [2], a novel sequential load balancing technique with reinforcement learning (RL)-based access point (AP) is discussed which reduces the system complexity. In [3], a novel handover approach has been proposed where the handover for a particular category is done, keeping in mind various attributes such as velocity of the user and quality of the channel in order to take the decision of handover. In [4], the impact of blockages and shadow formation is discussed. The experimental demonstration for a non-orthogonal multiple access (NOMA) Visible Light Communication (VLC) system with the use of Non-Hermit Symmetry (NHS) IFFT/FFT and other parameters such as transmitting distance and network coverage area are discussed in [5]. In [6], an optical ray tracing approach is studied in order to reduce the path loss in different link length for indoor laser-based VLC system which is done by defining the right positions for the transmitter and the receiver lowers to a point where the collection efficiency will be highest. The design for multiple VLC points for a hybrid system is discussed in [7], which aims in enhancing the data rate and improved capacity with respect to the desired demand as per the user. With the proposed SIC scheme, the interference from the neighboring array of LED can be reduced to a large extent. This is gaining a lot of attention from the researchers and industry as it is a road toward next generation (6G). In the proposed approach, as the user walks away from the LoS link, the light signals available to the user are lessened. The user may not receive the desired services as now it is not under the LoS (line-of-sight) link and FoV (field of view). Thus, there is an urgent need for an energy-efficient architecture for interference mitigation. With the proposed approach, there will be less complexity as the light beam is directed toward the demanding user according to its requirement, i.e., if a user wishes to upload or download a video or tends to do a video call, that user will be given utmost preference (here, A1). After the demands are fulfilled, the light emission for the said user is shut and the light signals do not interfere anymore to its neighboring cells with the help of SIC technique. Now, the demands for the user requiring light signals for voice or text will be given preference according to its need, considering the channel conditions.

In conventional VLC apex system, the users experience interference from its neighboring VLC apex points. This interference keeps on enumerating in traditional VLC APs and light from distinct VLC APs will intersect with one another. This hastens up the interference level and fall in the system performance. With our proposed approach, the mitigation of interferences is done with the help of SIC technique, and then further allocating the light signals to the desired users, with successive interference cancellation algorithm, the interferences are then successively cancelled out after satisfying the user based on its desired applications and their channel conditions.

3 System Model

The proposed system model drafted in Fig. 1 provides high speed data rate, high efficiency and low interference. The interference mitigation technique is done by SIC and then allocating the light signals to its desired users for attainment of high QoS and good QoE. With our proposed interference cancellation technique, the neighboring interferences are eliminated. This results in high QoS experienced by the users and

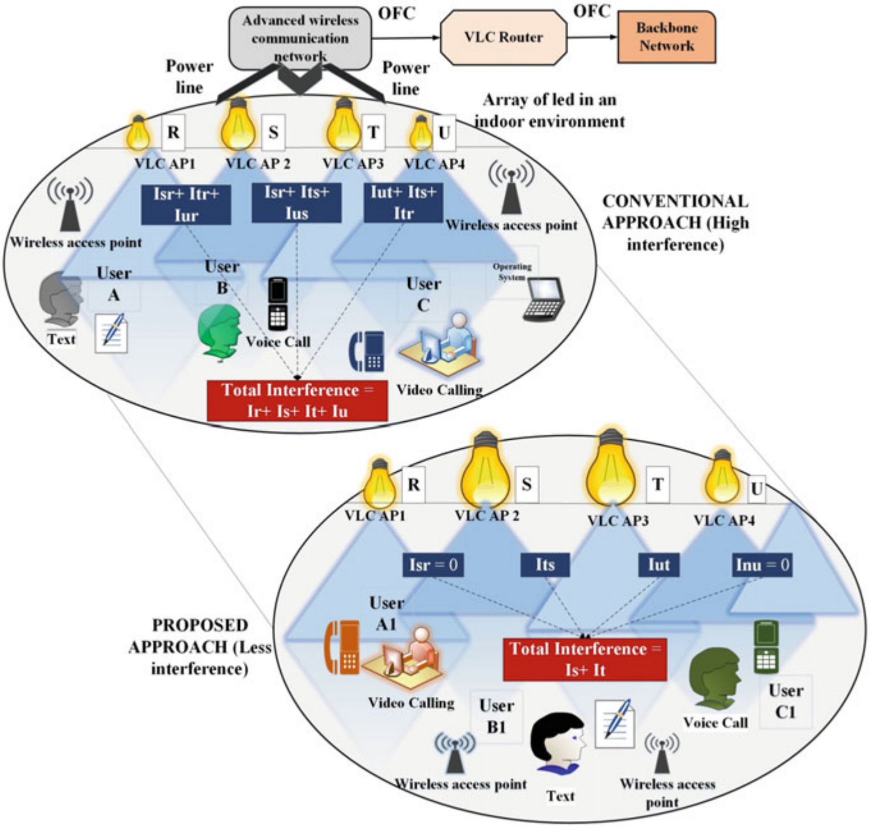

Fig. 1 VLC model for conventional and proposed approach

low complexity. The VLC system model with traditional and proposed approach is depicted in Fig. 1 as shown. The proposed system model helps in mitigating the interferences with the aid of Successive Interference Cancellation (SIC) scheme and allocation method.

The system model is deployed for an indoor room VLC system where the users are taken in a real-time scenario. Here, we have assumed three users A, B and C in case of conventional scheme and the users are at a certain distance to one another. The number of users may rise or fall for a general scenario. The transmitting power coming from the array of light emitting diode (LEDs) is fixed. The transmitter and the receptor must be in LoS for a proper communication to take place. The LEDs are connected to the VLC router and the backbone network with the help of advanced intelligent wireless network through optical fiber cable (OFC). The optimal channel conditions provide a better communication link for transmission and reception of signals. The reflectivity from various surfaces such as glass and wall is ignored here.

In conventional approach, LED transmits continuously the light signals whether a user demands for it or not leading to much more power loss and energy wastage. In this approach, the transmission and reception go on continuously. In conventional system, user experiences interference from various neighboring VLC access points (APs), and this interference keeps on adding and light from these VLC apex points will intersect with each other. The user will experience interrupted signal. This leads to low quality of experience (QoE) by the user.

We have considered three users A, B and C and A_1, B_1 and C_1 for the conventional and proposed approach, respectively. R (VLC AP_1), S (VLC AP_2), T (VLC AP_3) and U (VLC AP_4) are the apex points emitting light signals. The users in conventional and proposed approach require different applications as per need. In conventional approach, the subscribers will be interrupted by neighboring VLC APs. For example, here, R (VLC AP_1) will face interferences from S, T and U (Isr + Itr + Iur). Similarly, S (VLC AP_2) will get interference from R, T and U (Irs + Its + Ius). Thus, we see a constant addition in the interference level in the conventional approach. Interference and the SINR are inversely proportional to one another. Therefore, lesser the interference level, the better is the signal-to-interference-noise ratio (SINR) and vice versa. The addition in the total interference level lowers the overall system performance rate.

With the proposed approach, the interferences are mitigated to a large extent after fulfilling the users demand based on the channel conditions. The optimal channel selection is done considering the good signal strength. Here, h_1 is considered as the best channel path taken for the light signals to travel with. In our real-time scenario, firstly, the users are detected which are in need of higher signal strength and need services such as uploading or downloading or doing a video call and after that the channel conditions are seen. If the channel condition is apt, the light signals emitted and given to the desired user urging for video call and then the light beam is given to the users requiring services for voice call and text. Thus, we can say the services are given on priority basis to avoid excessive power wastage.

We will see a sudden drop in the interference level and high rise in the QoS experienced by the users. Interference tends to rise as the distance increases. Therefore, the users and the VLC apex points must be in FoV and in line of sight (LoS) to each other. Proper evaluation of channel conditions must be done to allot the signal strength to the desired users. The link which provides best channel condition for communication will be given first preference.

In case of the proposed approach, the interference will be eliminated and cancelled out from the total interference with SIC technique. With the proposed interference cancellation scheme, decoding of the signals and then subtracting the unwanted interference is done. All the VLC apex points would transmit light signals to the user which are in LoS and the optical-to-electrical convertor converts the optical signal into the electric data stream. After serving the desired user which is in line of sight and bearing good channel condition, this particular signal will be eliminated from the total signal strength. This reduces the interference level. This increases the data rate and provides good QoS and high capacity. In conventional approach, the interference factor is high which tends to lessen with the proposed approach (Fig. 2).

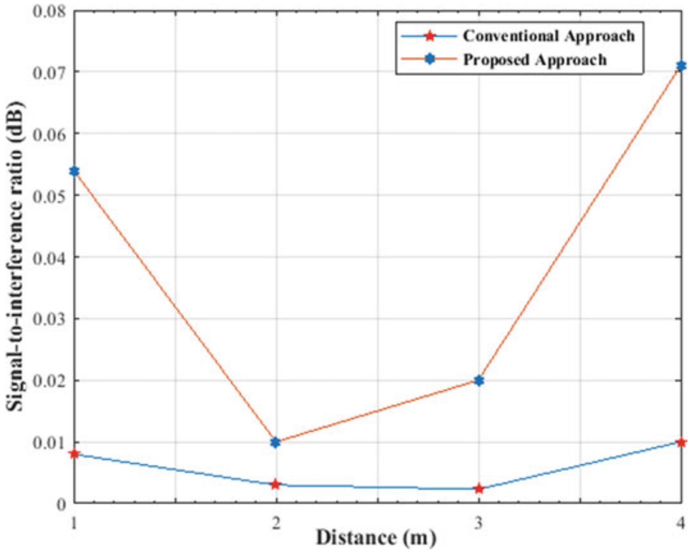

Fig. 2 SINR variation for conventional and proposed approach

The impact of the proposed approach will be seen with lowering of the interference concentration from the respective adjacent VLC APs. Since in the conventional approach, user experiences interference from the neighboring VLC APs and there will be fall in the SINR and low system capacity. But, with the proposed interference mitigation approach and SIC technique, there will be improvement in the SINR values and the capacity also increases. Thus, overall system performance rate gets enhanced. The energy and the spectral efficiency of the user get enhanced. The conventional system provides low data rate and high latency rate due to large interferences from adjacent VLC APs. Thus, we see fall in the overall throughput of the system. This is eliminated with the help of proposed interference mitigation technique.

The main agenda is to enhance the throughput and the performance level of the system. If the user moves away from the light source, the user may not receive the light signals so efficiently as the ones where transmitter and the receiver are perpendicular to each other. With the said proposed approach, the complexity is reduced. This leads to low power exhaustion. The user will enjoy high quality of service. The proper analysis has been shown below. The statistics collected in the table clearly show the rise in the SINR and the capacity with the proposed approach. The energy efficiency rises and the overall system performance rate gets enhanced.

4 Results and Analysis

With regard to the deployment scenario of the users for an indoor environment, the VLC APs and the users are at a distance of [1–4] m. The minimum number of users considered here is four for the real-time scenario. The count of the users may be high or low. The power emitted by the VLC APs is taken as 30 W. This optical wireless communication takes place with transmitter (here LED) and receiver (photodiode) being perpendicular to one another; that is, they must share LoS link in order to gain high signal strength of light signals. The probability of latency or delay signal strength is reduced in LoS communication. Thus, we see a high rise in the throughput level (as depicted in Fig 4) and the overall performance rate of the system. The neighboring or the adjacent VLC APs interference would be cancelled with the help of Successive Interference Cancellation (SIC) approach (Fig. 3).

In our system model, the results are formulated based on the simulations done on MATLAB for the conventional and proposed approach. This section illustrates the cancellation of the unwanted interference coming from neighboring VLCAPs in order to enhance the overall performance rate of the system. This paper shows the increased signal-to-interference-noise ratio (SINR) as it can be seen in the graph with the proposed scheme. The proper results and simulations have been performed.

The simulated results from Fig. 2 shows the SINR variation with respect to the user placed at different distances for an indoor VLC. It could be seen with each passing distance that the SINR increases for the proposed approach in contrast to the conventional approach. The graph depicts increased throughput rate, lower interference level and high SINR with the proposed approach. The increased throughput rate

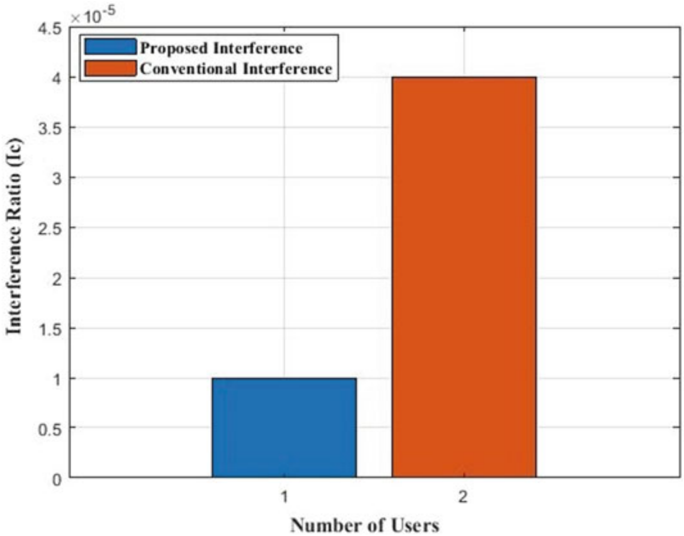

Fig. 3 Interference variation ratio for conventional and proposed approach

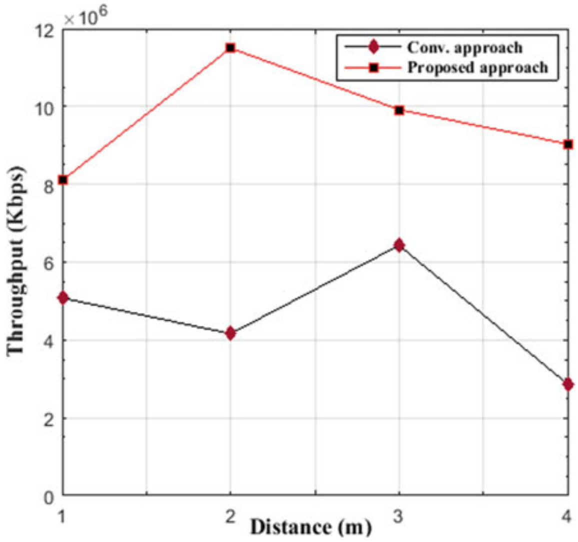

Fig. 4 Throughput versus distance (m)

for the proposed VLC indoor system is illustrated in Fig. 4, where 4 VLC AP and 4 users are deployed at 90^0 to each other so that they share LoS link. The distance is varied at each instant. The demands of the user are given priority based on the application demanded whether a person wants to upload or download, perform an audio call or simply text.

This priority-based approach is achieved by analyzing the channel conditions. If the channel conditions are favorable, the user's demand of desired application can be fulfilled without any delay. Thus, user enjoys high rate data services without any issue. There will be high-level interference issue from the neighboring VLC APs as the VLC APs are in close proximity to each other as shown in Fig. 1. Hence, the complexity of the system rises. Thus, the SINR and the throughput level of the system tend to fall as shown in Fig. 2. In contrast, there is an instant rise in the graph for the proposed scheme with respect to SINR and throughput as shown in Figs. 2 and 4, respectively. As shown in Fig.3, for the conventional approach, the interference keeps on adding due to adjacent VLC APs continuous transmission. Therefore, the graph sees a fall in the system performance rate for the same said approach.

When the interference is mitigated or gets reduced with the light cancellation SIC technique, the graph count sees a sharp increase in context to the overall system performance rate and the system capacity rises. With this approach, the VLC APs points concentrates its energy or emit light signals to the intended user and after the demands for the necessary services are fulfilled, and the interference is eliminated or gets subtracted from the total signal strength, thereby reducing the interference level and enhancing the throughput rate with a lead as depicted in Fig. 4.

The capacity values will vary as the SINR varies which is given by the below formula:

$$\Gamma_i = \frac{B}{2} \log_2(1 + \mathrm{SINR}_i), \text{ bps} \tag{1}$$

As the SINR varies, the capacity also changes. The hike in the SINR performance rate is shown in the graph above. For better capacity or throughput rate, the energy efficiency and the SINR must be high. The proposed approach is able to show variation in the throughput level and increased SINR due to the least amount of interference level. Thus, we can say lower the interference, better the performance rate of the system and the user enjoys high QoS. With this approach, a lot of power is saved thereby lowering the power consumption. Similarly, Fig. 4 clearly describes the overall increase in the throughput level with the movement of the user as per distance. Thus, we can say that with lowering of the interference the system efficiency rate enhances.

5 Conclusion

To meet the high end requirements by the users for high data rate and intensified applications, we are moving toward this new technique of eliminating the interference coming from adjacent VLC APs via mitigation technique. The mitigation of the interference and the enhancement of the overall system performance rate are done with the help of the proposed approach. The proposed scheme fulfills the high data rate demand by the users and increases the overall throughput of the system by lowering the interference level. This paper focuses on the analysis done for the conventional and the proposed approach. The difference between the two approaches is shown via simulation done on MATLAB. With the increase in the system's capacity, the subscriber gets high data rate and experience high quality of services. In near future, this indoor type of optical wireless communication may extend to outdoor communication too. A lot of research is going by the researchers on the VLC and its high tech use in the future for enabling optical communication to each household, labs, universities, etc. The use of array of light via VLC APs apex points reduces the power wastage and thus saves a lot of power consumption. This can be a great step toward 6G network**.**

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