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RESEARCH ARTICLE

Successive Light Interference Cancellation and Allocation (SLICA) Algorithm for Indoor VLC System: A Backbone for 6G Network

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ABSTRACT This paper considers a successive light interference cancellation and allocation algorithm (SLICA) practicing interference cancellation for an indoor visible light communication (VLC) system based on successive interference cancellation (SIC) technique. The interference among users is cancelled with the help of the proposed approach to reduce computational complexity. VLC has become the cornerstone of intelligence in the current scenario. The data services allocated to the users are demand based and rely on their channel conditions. The data is allocated to user by modulating light waves via illuminated LEDs. The receiving end has photodiode installed in it to recover back the data. Better performance rate is achieved with lesser interference with the proposed approach. To guarantee good (quality-of service) QoS, considerable simulations are carried out considering real- time scenario which further demonstrates the high level performance of the proposed approach over conventional approach. Based on the analysis, the SINR and interference level is demonstrated for the conventional and the proposed approach and there is a hike in the performance rate of SINR and interference level of about 20 – 30 % with the applied proposed approach. The prior motto of this study is to enhance the system throughput and improve per user average performance rate and reducing the complexity of the system. This contributes to the total efficiency of the optical indoor VLC network. Our proposed algorithm will provide a strong backbone for the 6G deployment.

INDEX TERMS Visible light communication (VLC), successive interference cancellation (SIC), QoS, EE, SLICA algorithm, optical fiber cable (OFC), SINR.

I. INTRODUCTION

With the extensive application of Led in indoor lightening, VLC technology is becoming much favorable for indoor communication system. A huge explosion in the demands of user for good QoS is being witnessed today. To satisfy this ever increasing demand and to attain the large bandwidth and faster connectivity, there is a serious need for some energy-efficient technique. There will always be rise in the mobile traffic so as researchers we need to forge on to some energy efficient techniques which provide high data rate services, consumes less power and is much more efficient than the conventional techniques. Thus, a pre-eminent change is needed to meet up the expanding interests of the users.

VLC serves as a vast area of interest. Visible Light Communication is a promising technology that could serve as a good alternative for the limited energy efficiency factor existing in the current Radio Frequency standard. VLC technology is sum of both communication and illumination where transmission of data is done via modulated light waves within a visible electromagnetic spectrum band, which has a range from 380nm-750nm and with a frequency spectrum of

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430-790 THz. With the escalating demands for services by the users, the array of Led tries to prioritize the demands of users and provide the necessary services to the respective user on priority basis.

The communication over direct links consumes less power and boosts energy efficiency and the overall system throughput. The Led ability to be modulated at high speed increases the possibility of using them not only for the basic illumination purpose but also for communicating. The high speed illuminating led offers the possibility of using simultaneous illumination and higher data rate communication. Such systems are referred to as Visible Light Communication (VLC) systems. VLC exhibits unlimited bandwidth and high throughput rate. VLC system is suitable for wireless indoor links due to easy installation and replacement of led. Led is highly energy efficient and have properties like durability and consumes less power with no harm to human life.

We can achieve high capacity and higher efficiency by directing the beam of light to a particular user falling perpendicular to the VLC Access Points (APs). Therefore, there will be reduction in interference level constraints. We can attain maximum throughput and much higher gain with the proposed SLICA algorithm. In this downlink VLC based network, the light signals are given to the users which are in line-of-sight (LoS) after meeting the favorable channel conditions. The rise in traffic increases the interference concerns. Such issues can be reduced with VLC followed up by some interference cancellation technique. A large number of schemes with improved data rates, higher energy efficiency have been investigated.

Currently, 5G networks are trying to meet its user demands with the technologies such as Massive MIMO, d2d communication, UDN. Out of all the said technologies, VLC technology turns out fully apt supporting direct linkage between transmitter and receiver with reduced power consumption and high data rates. VLC is safe and a secured network. A critical issue involved in this direct LOS linkage is interference from its neighboring VLCAP which can be mitigated through the proposed SLICA approach.VLC is gaining interest of researchers as it endorses high energy and spectral efficiency.

A. BACKGROUND OF RESEARCH

Li-Fi communication jointly performs the task of illuminating and communicating simultaneously over direct link formations. The aim of Li-Fi communication is to provide enhanced coverage for an indoor system, thereby satisfying user requests. The author in [1] presents various modeling techniques for indoor, outdoor, underground and underwater environments. A lot of research is carried out for the designing of an energy efficient system model which could reduce power consumption and has less complexity. The impact of blockages and shadow formation for an indoor VLC system has been investigated in [2]. The author in [3] experimentally demonstrate a non-orthogonal multiple access (NOMA) VLC system using Non-Hermit an Symmetry (NHS) IFFT/FFT and various parameters considering transmitter distance and network coverage.

An optical ray tracing approach has been studied in [4] to reduce the path loss in a variable link length indoor laser based VLC system. This is done by defining optimal positions of transmitter and receiver lenses to a point where collection efficiency is the highest. A fast and highly accurate single LED based Visible Light Positioning (VLP) system is proposed in [5], where the positioning accuracy of the system is increased while reducing the computational complexity. An optimal spatial modulation (OSM) scheme is proposed in [6], aiming at high data rates for indoor VLC system. A reflection based cooperative wireless system is proposed in [7] to connect APs using wireless connections. The design of a Hybrid system with multiple VLC access points and RF AP is proposed in [8] aiming at escalating data rates and improved through put depending on the user demand. In [9], the author discusses various applications of VLC and 5G at different layers such as physical and Medium Access Control (Mac) layer. The aim is to improve the throughput and the latency factor with the help of an architectural structural between RAN technology and VLC system.

Not much investigation has been done in cancelling out and mitigating the interference coming from its adjacent access points. With the proposed SLICA algorithm, the interferences are successively eliminated and then subtracted from the sum total of all the interferences which leads to low latency and high data rates and the user enjoys high quality-of-experience (QoE) and services without any delay factor, whereas as seen in case of conventional scenario, all the interferences gets added up and cause the latency and delay in light signals to be received by the user.

B. CONTRIBUTION

The contribution of this paper is to design and realize an optimal energy efficient algorithm for wireless indoor network to achieve high data rate with low latency, high energy efficiency, spectral efficiency and reduced computational complexity with the proposed algorithm. Some of the major contributions of this paper are multifold and are listed below:

1) In this paper, a successive light interference cancellation and allocation algorithm (SLICA) is proposed for wireless communication network (WCN) which reduces interference thereby muting the prerequisites QoS of the users with less complexity.

2) With this proposed framework, there is an improvement in receivers signal to interference noise ratio (SINR). High data rate is achieved with total boost in total system performance rate and energy efficiency (EE). Our target is to maximize the sum rate of the users using proposed algorithm so that users enjoy good QoS. VLC reduces the data traffic load from the existing RF schemes. VLC linkages could be a better substitute in universities, institutions and offices as it offers higher data rate.

3) The simulations depict that proposed scheme outperforms conventional VLC system with respect to throughput,

EE, SE and reduced interference levels. Also, the complexity for the proposed system reduces as compared to the conventional system with the mitigation of interferences.

C. ORGANIZATION AND NOTATION

The rest of the paper is organized as follow. The system model has been demonstrated in section II. The problem formulation is described in section III. Section IV elaborates the proposed algorithm. Section V illustrates the simulation results and describes how efficient the proposed approach is for indoor access of wireless system. The paper finally concludes in Section VI. The system parameters and various notations used in this paper are elaborated in Table 3.

II. SYSTEM MODEL

A. SYSTEM MODEL DESCRIPTION

With the high rise in the development of wireless technology and Internet of Things (IoT) in the smart cities and with the use of smart technologies like smart phones, indoor applications with VLC plays a vital role in providing high speed data rate and increase the system throughput as given in Fig(1). This section presents a system model analyzing high data rates, high efficiency and low interference level with the proposed SLICA algorithm. The proposed algorithm not only outperforms but also optimal in achieving high QoS. The overall architecture is depicted in Fig (4) for 5G lab. VLC router at the backend provides the necessary signals to the array of Led via the OFC. In our scenario, the array of led or the visible light communication access points (VLCAPs) provides significant light signals to the required users with prior consideration to the channel conditions. All the parameters are given in Table 3. As illustrated in Fig 1, a general system model for smart city is depicted where we find users experiencing a lot of interference from its neighboring access point. No synchronization of channel modeling is done to provide the desired light beam to its required user. This results in low QoS with high latency factor and high complexity among the users. This also leads to a lot of power wastage. The general expressions for the conventional and proposed approach have been obtained, with a general flow giving an overview and the working of SLICA. Channel gain, interference, SINR, capacity and various other parameters have been obtained for conventional as well as proposed approach to analyze the difference between the two.

At the receiver side, main component is the photo detector that detects and then regenerates the optical signal into an electrical signal. Assume VLCAP and mobile user transmission power level to be constant. Fig 3 illustrates the flowchart for the proposed algorithm to eliminate the unwanted interference from different access points. The services are allocated to the demanding users with the help of Led light. The Fig (4) helps in mitigating the interferences with aid of SIC technique and using the proposed SLICA algorithm. This results in enhancement of overall performance rate of the VLC system. The figure comprises of two hardware components used in the proposed system which mainly involves array of led or VLCAP (LED) where Led is the transmitting agent and photo-detector (PD) is the receptor. VLC major application is for indoor communication. The VLCAPs are mounted on the ceiling and each Led AP consists of numerous luminescent lights in itself. Led are used due to its various advantages. Led can replace the traditional light sources when it comes to long life, less power consumption, fast on and off switching quality, long durability and reliability. VLC is applicable not only for homes and indoor areas but could also be used in supermarkets, aircrafts, industries and hospitals. The white led is ideal for indoor wireless communication system as it is highly secured network exhibiting large bandwidth and consumes low power. It aims to provide high QoS to the user and guarantees large coverage area to the users especially to the ones which are in line-of-sight.

Within an indoor environment, definite possibility of interference from the neighboring VLC might exist. Not all the light that is being transmitted is received by the receptor. There are obstacles such as glass, wall wood [20]. This paper focus on eliminating interference as a major obstacle and the rest are explained in [20]. Here, we have assumed 4 users in case of a lab which are quite at distant from one another. We can even consider N number of users for other case. The interference from the VLC access points (APs) will exist depending upon its illuminating angle and considering line-of-sight (LoS) and Field of View (FoV) with respect to the user. Transmission power of the led (P_L) is assumed to be fixed. The transmitter and the receiver must be in LoS for the proper operation of communication process.

The channel condition plays a very keen role in transmission and reception of signals. The led keeps on transmitting optical signals to its respective demanding user. The light emission from the led source and the reception of these signals to the receiver goes on simultaneously. In case of conventional VLC systems, the users experiences interference from its adjacent VLCs and the interference keeps on adding and light from different VLCs will intersect with one other thus increasing the interference level and we see fall in the system performance. The optimal selection of channel is done in the proposed scheme where we have assumed $h_1 > h_2 > h_3 > h_4$ i.e. h_1, here bears best channel condition among rest. With the help of the proposed scheme, decoding and then cancellation of the individual signal from the total superimposed signal is done with the help of SIC the transmitter side. With our proposed approach SLICA, with successive light interference cancellation and allocation algorithm, the interferences are successively cancelled out after fulfilling the demanded application required by the user based on the channel conditions. Here, in real time scenario we have taken four users with four different VLC, assuming h_1 bearing the best channel condition. In case of the conventional approach, the $VLCAP_1$ tends to interfere to its neighboring sets but with SLICA enabled at the transmitter side; the light signals coming from $VLCAP_1$ will be transmitted and given straight to the $user_1$ since it has the best channel condition. With this,

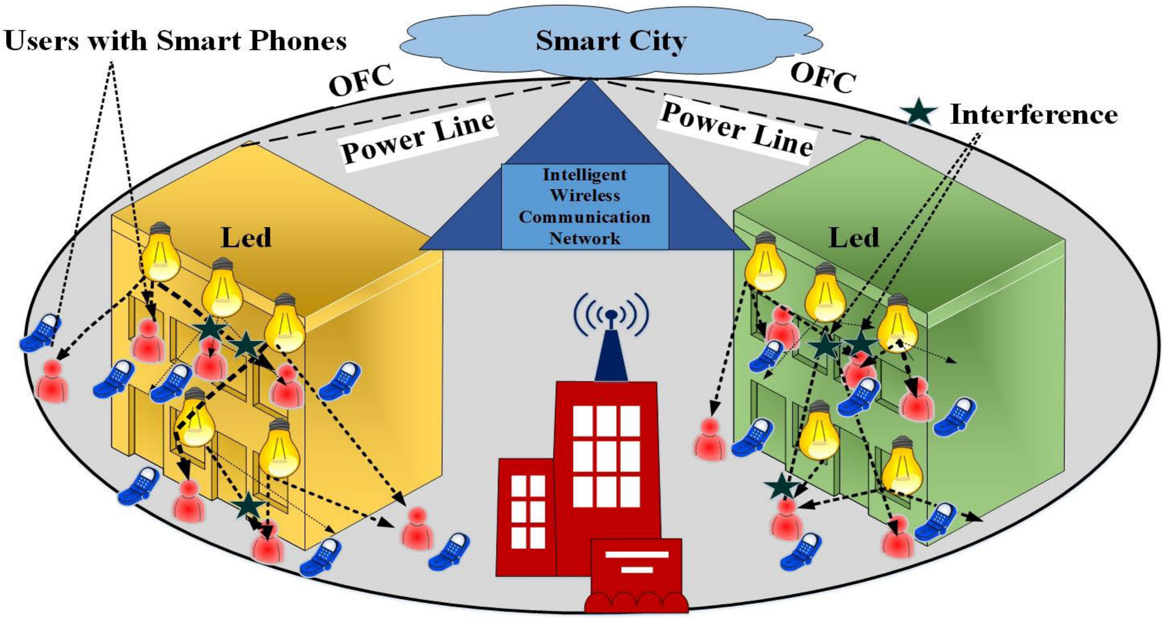

FIGURE 1. General system model for an indoor VLC system.

the optical signals coming from VLC1will not interfere into other user communication linkage as with the help of the proposed approach (SLICA), this interference is cancelled out after its communication process completes and will further not interfere in adjoining VLCAPs and disturb the communication process. Similarly, the second VLCAP will provide services to the user2 and after its demand is fulfilled based on the second high priority good channel condition, it will not interfere into the communication link in between user 3 and 4 and their respective VLCs. Such a series of successive cancellation of interference enhances the system performance level and opens up new opportunity in the near future for application of high- speed modulation led for illumination and communication purposes. Fig. 2 shows the block diagram for an indoor VLC system, depicting, the proper flow of the process with use of proposed algorithm and SIC. In real case scenario, many users are in close proximity to one other resulting in co- channel interference. The interference factor comes into effect only if the distance between the adjacent users is less than or equal to d_{max}. Let h denote the optical channel gain available to the user i. Here, we are considering $h_1 > h_2 > h_3 > h_4$ i.e. h_1 exhibits good channel condition than the rest. Similarly, h_2 bears better channel condition than h_3 and so on. Here, we have considered four users and four VLCAPs which are in Los to each other. At the receiving end, detectors or photo sensors are implanted in order to receive the light emitted by the led to continue speed communication thereby cancelling out other interferences using SLICA. The parameters for the proposed and conventional VLC system are fixed according to the value as stated in Table 3. The flow chart for the proposed algorithm is depicted in Fig3.

VLC has proven to expand wireless technology capabilities. In downlink VLC channel is taken as a unidirectional channel. VLC outperforms better throughput compared to Wi-Fi. High data rates and high capacity is achieved with RGB Led. VLC provides services with an enormous bandwidth capable of transmitting very high data rates with no bandwidth license.VLC bandwidth is approximately 10K folds to that of RF bandwidth. The luminaries (Led) used in VLC are highly energy efficient and use less power despite high light intensity and has low cost, making VLC system more economical. It can be used for both illumination and data transmission. There is no harmful impact of such transmitting sources on human health. VLC requires no high cost hardware equipments or antennas to transmit data. They possess intrinsic security. The control of transmitted data in physical layer is simple as in Los. This further avoids passive eavesdroppers to some extent. VLC can be applied in various sectors ranging from household level to factory level.

B. MATHEMATICAL MODELING

In this section, mathematical modeling is done to reduce the interference level with the proposed approach. At the transmitter side, the VLC is used to emit the light signals and this kicks off the communication process thereby satisfying high data rate and illumination requirements. In an optical wireless indoor system, the data is transmitted using the LED light through an optical medium to the receiver. Below are case analyses of the conventional VLC system and the proposed algorithm system.

1) CASE 1: CONVENTIONAL VLC (WITHOUT SLICA)

The optical channel gain with the directed and Los link conditions can be expressed as [15]:

$$h = \begin{Bmatrix} \frac{(\mathbf{m+1})\mathbf{A_r}}{2\pi \mathbf{d^2}} A_r T_S(\theta)\, g(\theta) \cos^m(\varphi) \cos(\theta) & \ominus \le \theta_F, \\ 0 & \ominus > {}_F, \end{Bmatrix} \tag{1}$$

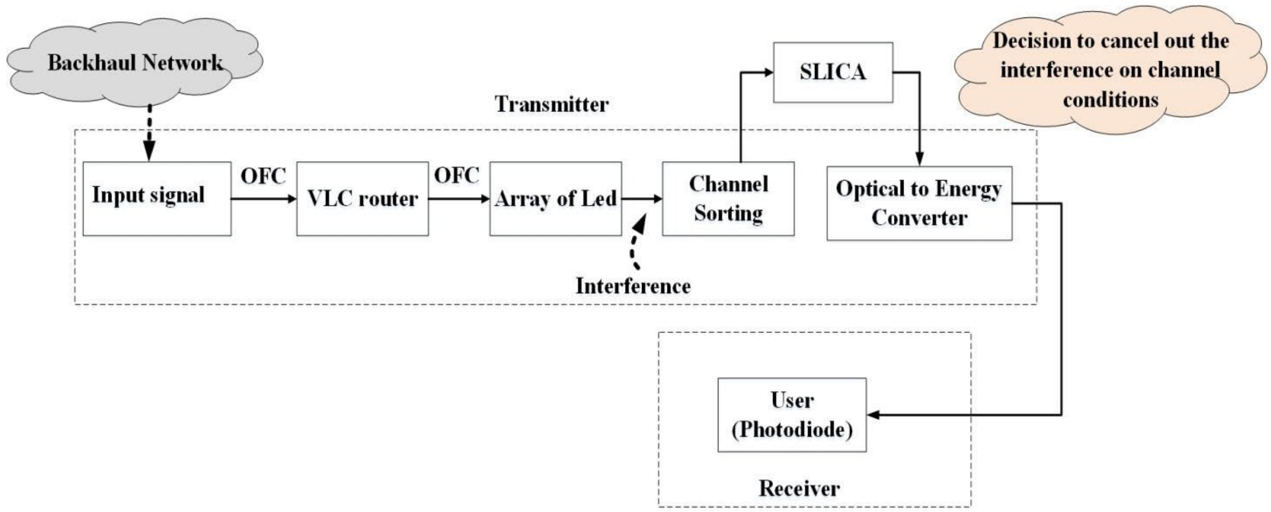

FIGURE 2. Block diagram of indoor VLC system.

Here, m is the Lambertian index which is a function of half the intensity radiation angle $\theta_{1/2}$, where, m $= -1/\log_2 (\cos(\theta_{1/2}))$; A_r refers to the physical area of the photodiode which is the receiving end; d is the distance from the VLC to the optical receiver; $T_S(\theta)$ is the gain of the optical filter; $g(\theta)$ is the concentrator gain; θ, is the angle of incidence;$_\Phi$ is the angle of irradiation; $\ominus_F$, is half the angle of the receiver's FoV. Theoretically, the concentrator gain $g(\theta)$ of the optical filter [11] and [15] is given by:

$$g(\theta) = \begin{Bmatrix} \frac{n^2}{\sin^2 \ominus_F} & 0 \leq \theta \leq \ominus_F \\ 0 & \theta > \ominus_F \end{Bmatrix} \tag{2}$$

Here, n represents the refractive index of the concentrator, and θ_F is the receiver or detector's FoV. In case of 'r' number of VLC AP and 'i' number of users, the signal-to-interference noise ratio (SINR) can be given [11] as:

$$\mathrm{SINR}_{ir} = \frac{(\gamma h_{i,r} P_L)^2}{N_0 B + \sum_{s \neq r} (\gamma h_{i,s} P_L)^2} \tag{3}$$

where, γ is the optical to electrical conversion efficiency; P_L,represents the power transmitted from a VLC AP; N_0, is the noise power spectral density; h_{ir}, is the channel gain between user i and rth VLC AP; and h_{is}, is the channel gain between user i and the interfering VLC AP 's'; Thus, 's' represents the number of interfering VLC access points. B, is the modulation bandwidth of the VLC. Here, we assume four users and four VLCs for a real time scenario, each user is served by a single VLC AP which has the largest SINR for that user and is in Line-of-sight (LoS). No signal is received by the photo detector if the incidence angle exceeds the Field-of-View (FoV) as no light falls directly onto the photo sensor.

The array of LED fixed on the ceiling for the given model provides sufficient illumination to the working area. For keeping the interference level low and SNR high, the distance between the transmitter and the receiver must be less. Thus, we can say light intensity is inversely proportional to the distance. the interference adds up for every user. Our main agenda is to cancel out the interference and increase the system capacity at the same time so that the user enjoys Quality-of-Service (QoS) with much improved per user average. With successive interference cancellation, the interference level is approximately nullified at the end. In this paper, the impact of interferences on conventional as well as on the proposed scheme are evaluated. The channel gain for the optical link for a real time scenario is calculated mathematically. We have taken four fixed VLC (LED) and four users which are perpendicular to one another. The optical channel gain for a LoS channel between the four sets of VLC and their respective users for the conventional case are performed and is given in Table 1 above. At different distances, the values for optical channel gain, interference and SINR in Los link is obtained and interference impact on the system is studied and the system complexity and less per user average throughput is seen. In the case of conventional optical system, each user's interference is added to see the delaying impact, loss of signal strength, low QOS and less capacity. For both the cases (with or without SLICA) same number of pairs is considered.

2) CASE 2: PROPOSED SLICA APPROACH

We have proposed a novel algorithm which aims at cancelling out the interference coming from the adjacent VLC access points thus improving per user average and enhancing system performance rate. The interference factor comes into the effect only when the distance between the adjacent pairs is less than or equal to $\ominus_F$. The cancelation and then subtraction of the unwanted interference from the total is a pivotal significance of SIC. The interferences are mostly from the ones having high channel gains. The non LoS communication is difficult to be met hence the source and the receiver must be in LoS for its operation.

TABLE 1. Channel gain and interference values for d = 1, 1.5, 2 and 2.5 for conventional VLCAP.

Distance (in m)	Channel gain (h)	Interference (I)	SINR
d=1	$h_1 = 0.0000079$	$I_1 = 0.00002$	$SINR_1 = 0.039$
d=1.5	$h_2 = 0.0000035$	$I_2 = 0.00001$	$SINR_2 = 0.008$
d=2	$h_3 = 0.0000019$	$I_3 = 0.0000057$	$SINR_3 = 0.0023$
d=2.5	$h_4 = 0.00000127$	$I_4 = 0.0000038$ $\sum_1^4 = I_1+I_2+I_3+I_4 = 0.000039$	$SINR_4 = 0.001$ Total SINR = 0.05

With the proposed Successive Light Interference Cancellation and allocation algorithm (SLICA) as investigated in this paper, proper decoding and then omission of undesired interferences at the transmitter side is done. We have assumed h_1 having best channel condition i.e. $h_1 > h_2 > h_3 > h_4$. So, $VLCAP_1$ will transmit light signals to the $user_1$ on its sub channel and this optical signal is converted into electrical signal by the optical to electric convertor. The proposed approach aims at extricating out the details of the VLCAP and user pairs bearing high or the best channel conditions. After providing the desired signal to the user in line-of-sight having highest channel gain, this signal will be cancelled or subtracted from the total signal. This eliminates the interference. The VLC starts to transmit the light signal to the user using air as the transmission medium depending on the channel conditions. We have here assumed h_1 having best channel condition therefore VLC_1 will transmit signal to the $user_1$ having highest channel gain. This $pair_1$ (VLC_1 and $user_1$) will now be subtracted from the sum of all interferences and shall not interfere in process of other pairs. Now pair $_2$ ($VLCAP_2$ and $user_2$) will face interference from the adjacent light sources i.e. VLC_3 and VLC_4 represented by $I_{32}+I_{42}$. The VLC_4 will have less effect on $pair_2$ (VLC_2 and $user_2$) due to the distance constraint. So there will be more interference from $VLCAP_3$ to the second and similarly, there would be interference from $VLCAP_4$ to third pair. So there will be more interference from $VLCAP_3$ to the second and similarly, there would be interference from $VLCAP_4$ to third pair. Therefore, here only two interferences will be in effect.i.e. I_2+I_3.The fourth user will experience no interference similar to first with the help of SIC technique used so that the user enjoys good quality of service (QoS) with much improved per user average. Mathematical calculations are being done for proper evaluation as given in the table below. All other parameters for finding out channel gain, interference and SINR will remain same as mentioned in Table 1. The channel gain will remain same as in conventional case but the SINR will vary and is given below:

$$SINR_{ir} = \frac{(\gamma h_{i,r} P_L)^2}{N_0 B + \sum_{s \neq r} (\gamma h_{i,s} P_L)^2 - I_1 - I_4} \quad (4)$$

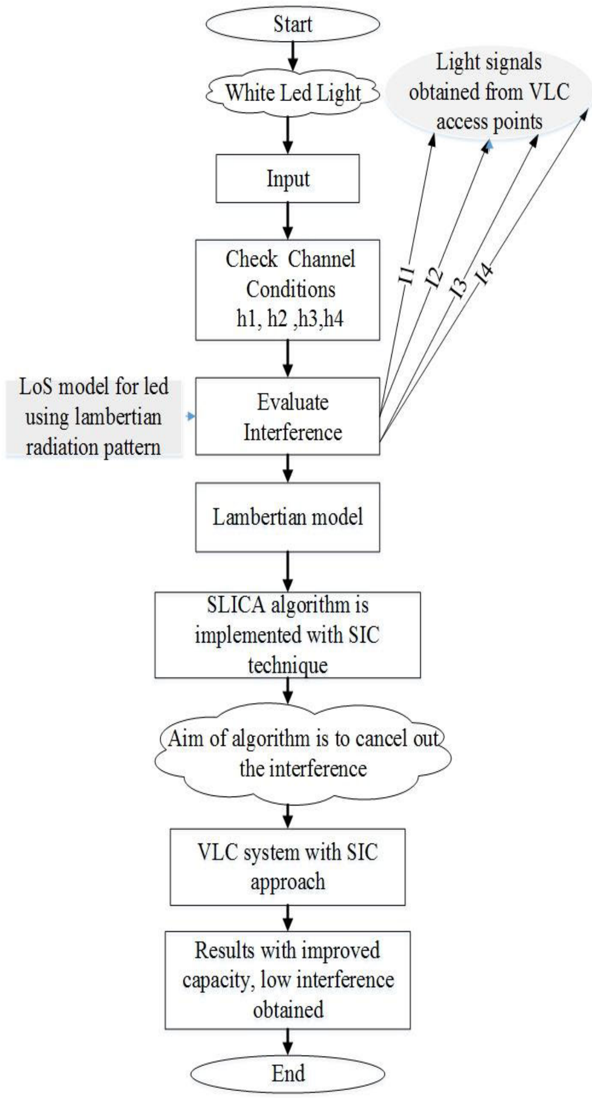

FIGURE 3. Channel gain flow chart for the proposed algorithm.

Here, we are subtracting the interferences (I_1 and I_4) as they do not interfere into the adjacent pairs and with this approach, the total interference level will fall and users will enjoy high data rate services and high sum rate. But in case I (conventional case), the interferences are added from all the other VLC access points (APs). Also, in Fig 4, the top most side (without SLICA/conventional) defines that $I_{21}+I_{31}+I_{41}$ are the interferences that user1 is facing. '+' sign here only represents the addition of all the interferences since it is a case of a real time scenario. Similarly, $I_{12} + I_{32} + I_{42}$ are the interferences faced by user 2 due to VLC APs 1, 3 and 4 respectively.

From the above analyses we conclude that interference is high in the conventional VLC system due to no interference cancellation scheme applied and $user_1$ faces interference from VLC_2, VLC_3 and very less interference from VLC_4. Similar trend goes for $user_2$ and so on. With our proposed

SLICA approach considerable reduction in the level of interference can be seen. The interference level lessens at every step with the proposed algorithm and SIC technique used and successively the interference is cancelled out after channel sorting. This lowers down the interference level thus resulting in high data rates, good QoS and higher capacity whereas in case of conventional approach, the interference is more and this will continue to shoot up with increase in number of pairs of VLCs and the led. It can be seen from the Fig no.(4), there is rise in the interference level in conventional case (Without SLICA) which we seek to lessen with our proposed approach (With SLICA).

III. PROBLEM FORMULATION

This section focuses on maximization of system sum rate so that the demanding users enjoy good QoS by cancelling out the interferences coming from the adjoining VLC. The transfer of light energy from the VLC access point must be uniformly radiated rather than radiating in an isotropic manner. Therefore, uniform radiance from the light source to the user is very important in optical communication system so that user enjoys high signal strength services. The receiver must be in FoV to the transmitter in order to enjoy high speed continuity of signal. The source and the receiver must be in LoS (Line- of –Sight) for its proper functioning.VLC communication supports only short range communication. It is chiefly applied for indoor area and could be extended in the future generation to outdoor environment too with the help of connecting led and neighbor hood access points, thereby creating LAN (Local area network).

This could be further connected to establish WAN. Therefore, there is large scope of investigation for the researchers to look in the VLC system in the next generation networks. In our scenario, the mitigation of the interference effect at the receiver side is done using the proposed SLICA algorithm. The configuration of which is depicted in fig4. Low interference level is achieved by subtracting the unwanted interferences from the total signal which provides high SINR. The signal-to-interference noise ratio (SINR) in conventional case [11] is given as:

$$\mathrm{SINR_{ir}} = \frac{\left(\gamma \mathrm{h_{i,r}} \mathrm{P_L}\right)^2}{\mathrm{N_0 B} + \sum_{\mathrm{s} \neq \mathrm{r}} (\gamma \mathrm{h_{i,s}} \mathrm{P_L})^2} \tag{5}$$

Therefore, uniform radiance from the light source to the user is very important in optics so that user enjoys high signal strength. The cancellation of the interferences at the receiver side is done using the proposed SLICA algorithm and SIC technique used at the transmitter side. The configuration of which is depicted in figure1. The deduction of the interferences is achieved by subtracting the unwanted interferences from the total signal which provides high SINR and boosts the system performance rate. The signal-to-interference noise ratio (SINR) in conventional case is given by eq. (6):

$$\mathrm{SINR_{ir}} = \frac{\left(\gamma \mathrm{h_{i,r}} \mathrm{P_L}\right)^2}{\mathrm{N_0 B} + \sum_{\mathrm{s} \neq \mathrm{r}} (\gamma \mathrm{h_{i,s}} \mathrm{P_L})^2} \tag{6}$$

TABLE 2. Channel gain and interference values for d = 1, 1.5, 2 and 2.5 for proposed VLCAP approach.

Distance (in m)	Channel gain (h)	Interference (I)	SINR
d=1	h_1 = 0.0000079	I_1= 0	$SINR_1$ = 0.027
d=1.5	h_2 = 0.0000035	$I_{2,3}$=0.00001	$SINR_2$ = 0.054
d=2	h_3 = 0.0000019	$I_{3,4}$ = 0.0000057	$SINR_3$ = 0.016
d=2.5	h_4= 0.00000127	I_4 = 0 $\sum_1^4 = I_1+I_2+I_3+I_4$ =0.000015	$SINR_4$ = 0.0071 Total SINR= 0.34

And, the resulting signal after subtraction of unwanted interferences is given by equation (7) below using the SLICA algorithm similar to eq. no (4) above.

$$\mathrm{SINR_{ir}} = \frac{\left(\gamma \mathrm{h_{i,r}} \mathrm{P_L}\right)^2}{\mathrm{N_0 B} + \sum_{\mathrm{s} \neq \mathrm{r}} (\gamma \mathrm{h_{i,s}} \mathrm{P_L})^2 - \mathrm{I_1} - \mathrm{I_4}} \tag{7}$$

The light signal once received is demodulated once detected and then is eliminated from the total VLCAPs. Such a process continues up to the n number of pairs here, 4 VLCs. The first and the last pair receive its own light signal from their respective VLCs. The elimination process leads to low interference level and enhancing the overall system performance.

IV. SUCCESSIVE LIGHT INTERFERENCE CANCELLATION AND ALLOCATION ALGORITHM (SLICA) FOR BETTER PERFORMANCE RATE

The decoding of two or more packets that arrives simultaneously at transmitter, in a wireless data transmission network in order to avoid collision is called Successive Interference Cancellation. The users suffer interference from its adjacent VLC sources having high channel gain conditions. This results in high interference which unfortunately affects the SINR computations. Thus, we can say SINR and interferences are inversely proportional to each other. Clearly, low interference level improves the SINR, thereby attaining achievable data rates and increase in per user average. The overall power consumption also reduces hence increasing the life span of the Led. The proposed approach explores how the interferences can be reduced in this section. Here, SIC is employed at the transmitter where the process of decoding, detection and then elimination of the strongest signal first, keeping in mind the channel gain condition.

The light signals are transmitted to the demanding user lying perpendicular to it or are in los. After delivering the optical signal to the user, this pair of VLC and user will not interfere to the adjacent pairs. At last, this I_1 is subtracted from the total signal. Thus the channel sorting is done first for the APs with high channel gain and then extracted out from the sum and interference cancellation is done with SIC

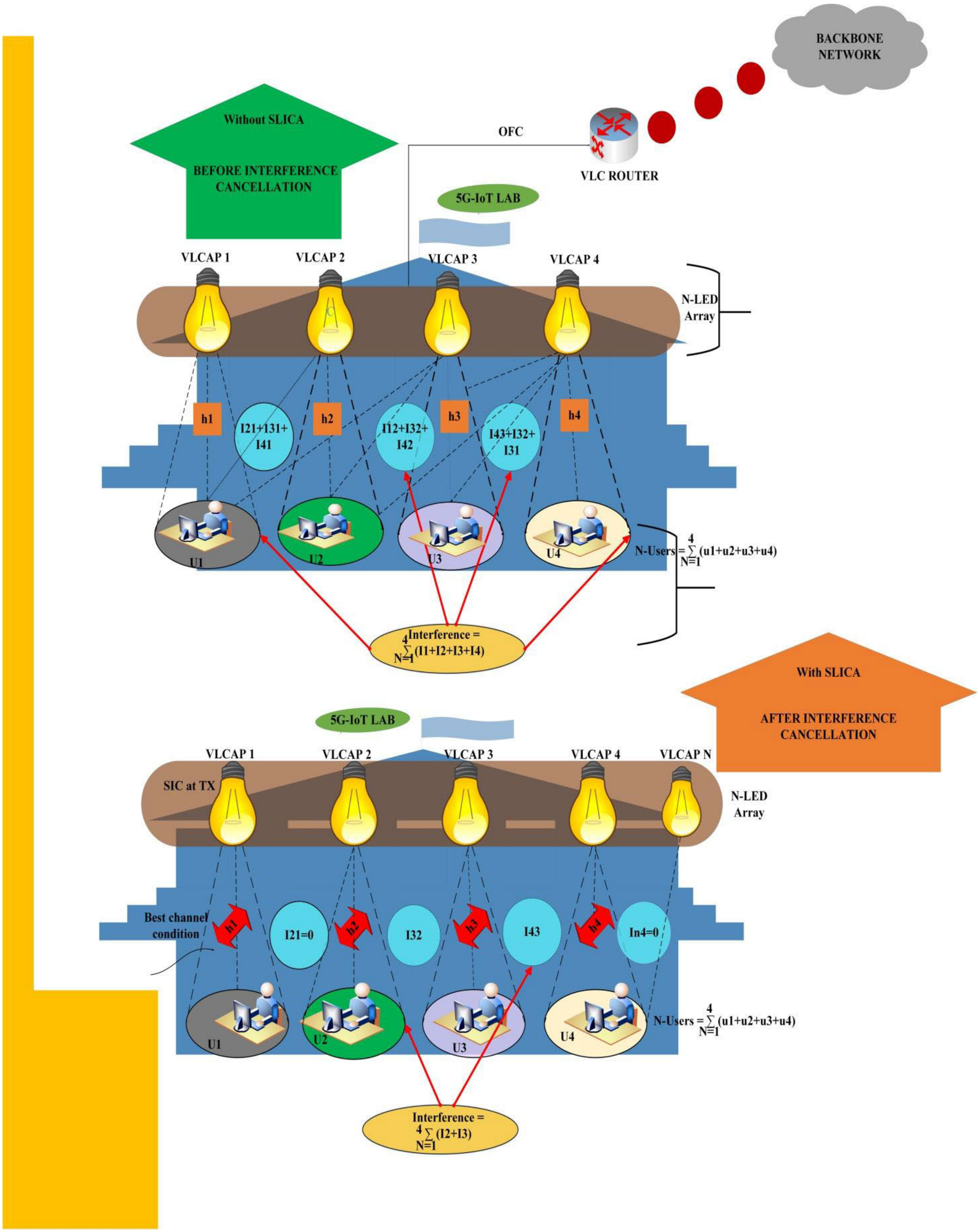

FIGURE 4. Illustration of an indoor VLC system using Proposed SLICA algorithm for interference cancellation.

so that the remaining signal receives less interference from its neighbor. Thus, the light signal once decoded is eliminated from the total signal. This however helps in elimination of interference.

TABLE 3. List of symbols and variables used in SLICA.

Name of the Parameters	Symbol	Value	Unit
Half-intensity radiation angle	$\theta_{1/2}$	90^0	degree
Photo detector's physical area	A_r	$0.0001m^2$	Meter square
Gain of optical filter	$T_s(\theta)$	1	-
Angle of incidence	θ	0^0	degree
Angle of irradiance	Φ	0^0	degree
Concentrator gain	$g(\theta)$	1	-
Refractive index	N	1.5	-
Distance	d	1,1.5, 2 and 2.5 m	Meter
Modulation bandwidth for VLC	B	40MHz	Mega hertz
Optical to electric conversion efficiency	Γ	0.55A/W	Ampere per watt
Transmitted optical power per VLC	P_L	10 W	Watt
Power of the mobile user	P_U	3W	Watt
Noise power spectral density	N_0	10^{-21} A^2/Hz	Ampere square per hertz
Lambertian index	M	- 0.5	-

Basically SIC, has the ability to decode the information of the individual signal from the total signal. With the aid of SIC, the capacity of the indoor wireless network improves significantly. With SIC, the strongest signal having best channel condition is decoded first, treating all other as interferences. The original signal is then reconstructed and decoded by the user and is further eliminated (cancelled) from the total signal. Similarly, the next strongest signal is decoded from the remainder.

Therefore, successive interference cancellation (SIC) is an iterative process to achieve strongest signal strength for each user. In this paper, interference cancellation is performed twice considering four VLCs with high channel gain of $VLCAP_1$ having the strongest signal strength as we have considered $h_1 > h_2 > h_3 > h_4$. We can conclude, SIC employed in the suggested proposed approach enhances the SINR, thereby improving the system throughput. A similar analysis can be done for any "N" number of pairs.

A. IMPACT OF SLICA ON INTERFERENCE CANCELLATION AND CAPACITY IMPROVEMENT

The users will suffer interference from nearby VLCs due to high channel gain resulting in high interference values which adversely affects the SINR computations. This section investigates how interference is reduced with the proposed approach, with SIC implanted at the transmitter end. Here, we have taken 4 users in real time scenario where; $|h_1|^2 \geq |h_2|^2 \geq |h_3|^2 \geq |h_4|^2$, with h_1 exhibiting best suitable conditions and with the implementation of the proposed scheme VLC_1 will provide demanded services to $user_1$ after which VLC_1 pair will not be able to interfere to its neighboring pairs and hence gets eliminated from the scenario. This process goes on and enhances the system performance and increases SINR which is given in the eq. (8) below:

$$\text{SINR} = \frac{\textit{Received Power}}{\textit{Noise Power} + \textit{Interference}} \tag{8}$$

Here, we can say SINR and interference are inversely proportional to each other. Clearly, we can see that reduced interference improves SINR, thereby supporting improved achievable data rates and EE. Based on the expressions obtained for SINR at the receiving end for n number of users, the expression is given in equation (4), where the sum total of the interference is considered. In this type of conventional approach, the VLCs will experience interference from the all of its adjacent pairs depending on the signal strength of respective VLCs. The interference experienced by each VLC is the sum total of all the interferences from different VLCs and is denoted as

$$I_{\text{TOTAL CONV.}} = \sum I_1 + I_2 + I_3 + I_4 \tag{9}$$

The proposed SLICA approach employs Successive Interference Cancellation (SIC) scheme at the transmitting end of each VLC. The new SINR equation for SLICA is given in equation (7) where the pair exhibiting good channel conditions will be allocated the demanded signal. After the allocation of light signal to the required user, this encountered

TABLE 4. Capacity and energy efficiency values for conventional and proposed approach.

Approach	SINR	Capacity (Mbps)	Energy Efficiency (Mbps/watt)	Spectral Efficiency bps/Hz
Conventional	0.05	1.4	0.14	0.03
Proposed SLICA	0.34	8.4	0.84	0.21

interference is canceled and then eliminated from the total signal and is given in eq. no (10) below:

$$I_{\text{TOTAL SLICA}} = \sum I_2 + I_3 \tag{10}$$

where, the interference will have high channel gains and superior signal strength are first allotted the demanding user and then is eliminated from the total signal, this eliminates the interference level to a large extent thereby enhancing the system throughput. This paper helps in limiting the interference level with the aid of SIC to achieve high channel capacity.

B. IMPACT OF SLICA IN ENHANCING ENERGY EFFICIENCY, POWER SAVING

The direct link communication saves power consumption and boosts up the energy efficiency. The goal of green communication can be achieved with the proposed algorithm as it uses LEDs which are not only highly energy efficient but are desirable for their low heat generation. LEDs can durable and has an advantage of switching on and off at extreme high rates. The overall power consumption is also low with use of LED thereby increasing its life span. The required services demanded by each user is fulfilled via transmitting light signals from their respective VLCs with the aid of SIC scheme and lastly cancelling out the interferences with the help of the proposed scheme. Energy efficiency which is defined as the rate of capacity linkage over the average power consumption is given in eq. (11) below:

$$\text{EE} = \frac{Capacity}{Power} = \frac{\beta \; log2\,(1+\gamma)}{Power} \tag{11}$$

V. SIMULATIONS RESULTS AND DISCUSSIONS

The simulation parameters for the proposed SLICA algorithm have been illustrated in Table 3. The light source and the user share a channel modeled as Line of sight (LoS) in which the users which is LOS or is perpendicular to the light source i.e. VLC demand services from it keeping in mind the channel conditions. This section investigates the proposed algorithm, derived to cancel out the unwanted interferences in order to boost the overall system performance rate. This is a case for a realistic scenario for an indoor environment, here taken the case of a 5G IoT lab. The proposed approach is contrast to the conventional approach and the results proclaim the satisfactory performance of the proposed approach to that of the conventional one. We assume 4 illuminating LED sources and 4 users with varying distance and the density of users may increase later for N number of users. On the basis of the applied realistic scenario, simulations and proper analysis are conducted using MATLAB. The area of from the simulations have been discussed and inferences have been drawn which are summarized below.

A. CAPACITY ANALYSIS

The improved capacity performance for the proposed VLC indoor system is analyzed in Fig. 5. In this case, 4 users and four VLC are deployed perpendicular to each other so that they are in line-of –sight to one another at different distances. Each user demands different application and the respective VLC access point job is to fulfill them by checking their channel conditions. With the deployment of SIC at the transmitter side, after the demanded services gets fulfilled the respective VLC will not interfere in to the corresponding VLC and users pairs and thus will be eliminated from the scenario. This enhances the throughput of the system. In case of conventional approach, the capacity is given as: $\Gamma_i = \frac{B}{2} \, log_2 \, (1 + SINR_i)$, bps and the calculated value is given in Table 4.

Similarly, in case of the proposed approach the capacity formula will be same but SINR values will vary. With rise in SINR value for the proposed approach we observe high rise in the capacity values as can be seen from Fig (5). The rise in SINR with the proposed approach with use of SLICA can be seen in the Figure above. The SLICA- Proposed exhibits high capacity due to lesser interference levels (using SIC). This enhances the overall system performance and the user enjoys high Quality-of –Services (QoS).

B. ENERGY EFFICIENCY EVALUATION

In Fig.6 we note the same fashion of increase in energy efficiency similar to the capacity analysis. High rise in energy efficiency leads to fast linkage communication between the trans-receiver. Since the transmitter and the receiver are in line -of–sight to each other, low energy losses are there. Led requires low energy to switch on and off hence led are efficient enough in saving power and simultaneously fulfilling the users demand.

The figure depicts that the proposed SLICA algorithm is much more energy efficient than the conventional approach. The goal of power consumption is also attained with the proposed algorithm with optimal energy efficiency. The reduction in the interference level also has a pragmatic effect in enhancing energy efficiency. The simulation result shows that the energy consumption outmatches in comparison to the conventional networks with the proposed approach.

C. SPECTRAL EFFICIENCY ANALYSIS

The efficiency of transmission of data over a specific bandwidth in a wireless communication system is called as

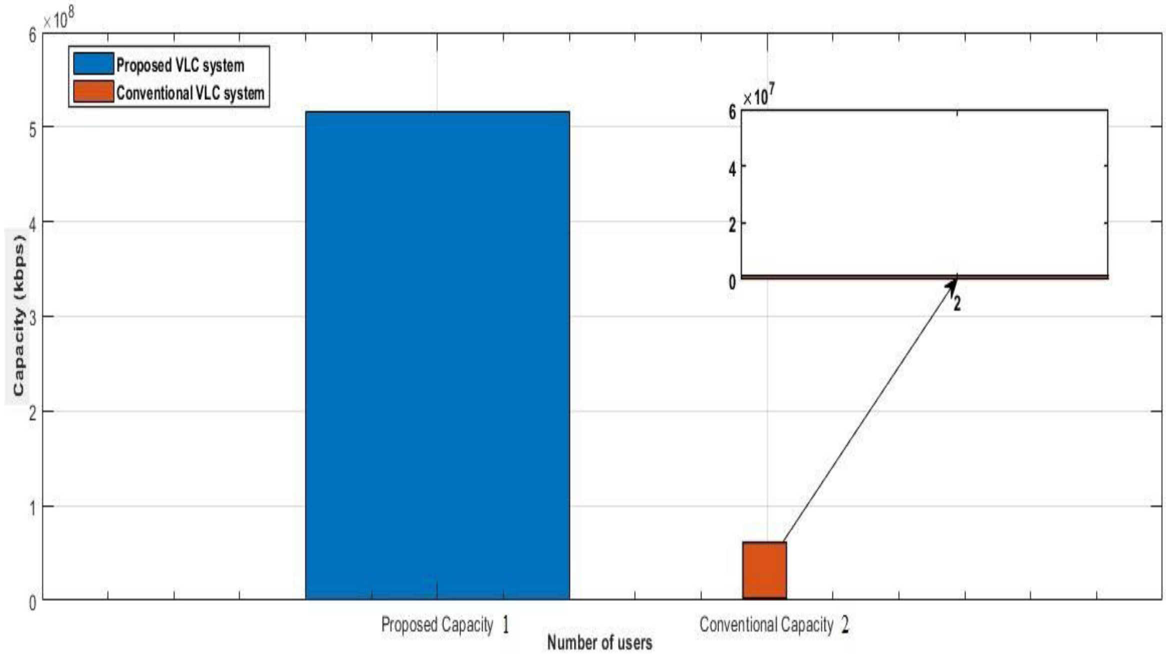

FIGURE 5. Comparison of capacity v/s number of users for conventional and proposed VLC system.

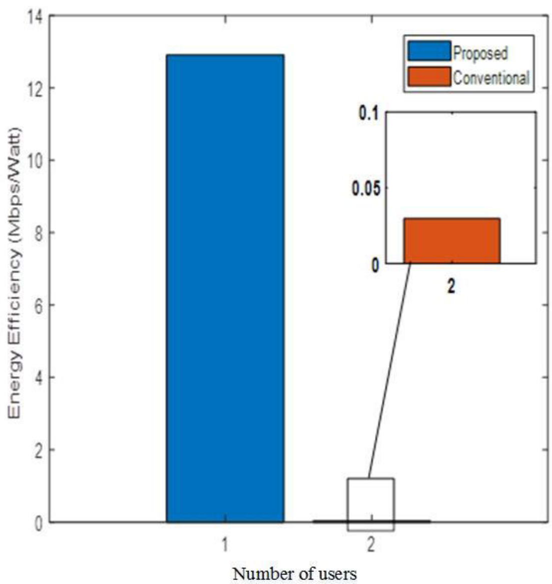

FIGURE 6. Energy efficiency analysis for conventional and proposed approach.

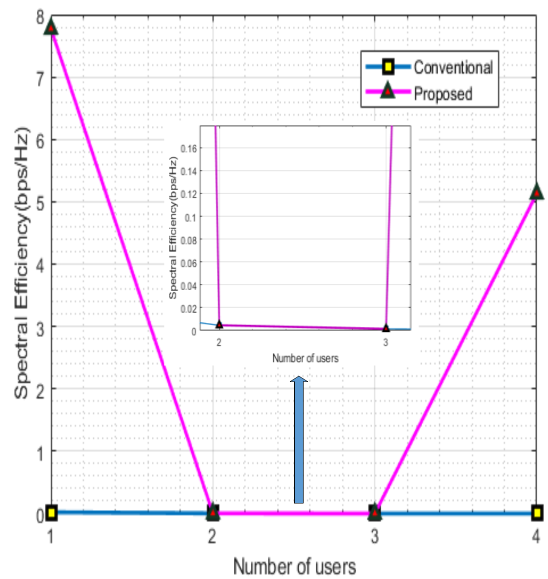

FIGURE 7. Spectral efficiency analysis for conventional and proposed approach.

spectral or bandwidth efficiency. With the use of SIC technique, the access of transferring of data to more number of users for an indoor area is easily feasible. The performance of conventional and the proposed approach are compared to figure out high rise in its spectral efficiency as shown in Fig.5. The figure depicts the rise in spectral efficiency achieved by proposed approach due to SIC technique. It is given by the formula in eq.(12) below:

$$n_{SE} = \frac{Capacity}{Bandwidth} = log_2\,(1+\gamma); \tag{12}$$

It is clear from the figure that low spectral efficiency is achieved in case of conventional and maximum in case of proposed approach. Good spectral efficiency is inspected to deliver high QoS to the user and achieve better performance rate. This can be ratified with the numerical results and huge inflation in the spectral efficiency can be observed with the proposed scheme. If the users are less and in line-of-sight to the light source, it will experience high spectral efficiency and high data transfer is possible over the given bandwidth.

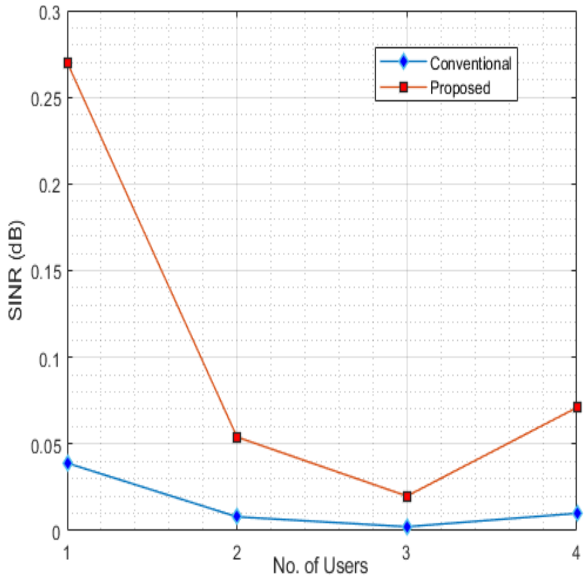

FIGURE 8. SINR analysis for conventional and proposed approach.

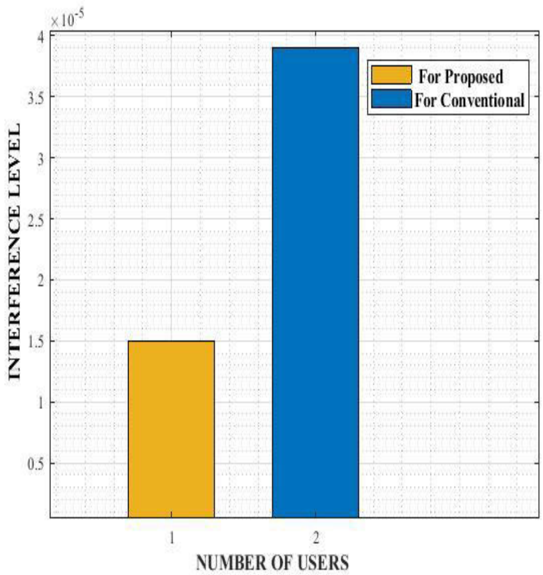

FIGURE 9. Interference analysis for conventional and proposed approach.

With the rise in signal-to- noise (SNR), the spectral efficiency improves. More proportion of data could be served to the accessible bandwidth to use it wisely.

D. SINR ANALYSIS

The performance of the proposed SLICA algorithm with high SINR is analyzed in Fig (8). The numerical results substantiate the trade off in between the conven -tional and proposed SINR. Interference has direct effect on the performance of the user. The proposed algorithm uses interference cancellation method to reduce the interference level. As seen from the fig (8), the proposed approach yields better SINR performance than the conventional approach. To attain high capacity and energy efficiency the SINR must be high. It is well validated from the below figure.

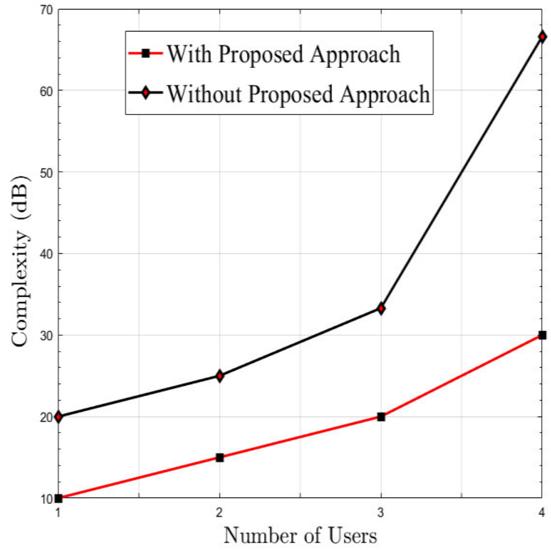

FIGURE 10. Complexity analysis for conventional and proposed approach.

E. INTERFERENCE EVALUATION

The light coming directly from the optical transmitter (LED) tends to experience interferences from other VLC points existing in parallel giving rise to co-channel interferences. Due to the introduction of the proposed SLICA algorithm, there is an exponential increase in the SINR and interference factor reduces which boosts up the system performance. Interference evaluation is very important in the VLC system. The Fig. 9 depicts the rise in the interference level in the conventional approach and reduction in the interference level with the proposed SLICA approach. This enhances the overall system efficiency. Some robust system design and architecture is needed to mitigate the interference level.

F. COMPLEXITY ANALYSIS

The system performance deteriorates greatly due to multiple optical light sources sending beam of light continuously to its users in the VLC network whether the user requires the given services or not. This cause interferences and disturb the mobility of the network. Also, a lot of power wastage is seen in case of conventional approach. In our proposed approach, with SLICA we have reduced the power emitted as the power will be used only when user demand services and continuous power is not given. And once the user demand gets fulfilled the power is shut off as the light beam is no longer allowed to give the unwanted signals.

Our power consumption ratio also gets reduced due to the proposed approach, hence less power is required for the communication to take place. This overall reduces the system complexity but in conventional approach since no mitigation approach is applied we see severe complexity in the system and overlapping of the interference too in the graph shown above. This problem of power exhaustion could be successfully mitigated with the proposed SLICA approach. It is comprehendible from Fig 10 that minimal complexity is obtained for SLICA - proposed, and maximal in case of conventional approach. With more number of users or light sources, the complexity rises. Fig.10 anticipates the method to take out complexity for the proposed approach. With low interference at the end, proposed approach complexity reduces.

The simulation result clearly validates the usefulness of the proposed SLICA algorithm for the indoor VLC system. The interference impact is lessened in the proposed network. Also, in both the approaches (with or without SLICA) we have taken equivalent number of users and illuminating light sources. Our main focus is to lessen the interference and complexity factor in order to enhance the overall system performance.

VI. CONCLUSION

An algorithm is introduced to revamp the VLC system. The main aim is to cancel out the interference using the proposed approach and its potency is realized by the simulation results. A robust network architecture is required to guarantee QoE and QoS to the users. The goal of green communication can also be achieved with use of LED as it aims at using energy efficient Led that generates low heat which are no harm to the environment. It is a secure communication. This paper aims for an optimized energy efficient framework from the security point of view as VLC is a highly secured network. The power consumption is low as led has the ability to switch on and off at extreme rate. High transmission data rate can be achieved with use of optical transmitters. The proposed scheme eliminates the interference coming from the adjacent light sources. VLC overcomes the bandwidth limitation of radio frequency (RF) standard as it supports larger bandwidth. The results reveal that the proposed approach effectively enhances the capacity and data rate as compared to conventional approach. The whole focus is to boost up the system performance and to achieve low complexity and increase in the system throughput. VLC is gaining the interest of the researchers as it endorses high energy and spectral efficiency thereby improving system performance rate. VLC is considered as the strong backbone for the 6G network.

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