Performance Analysis of Visible Light Communication for Web of Things

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Abstract: Nowadays, there are several IoT devices and that IoT devices use radio frequency for wireless communication. Due to growing popularity of IoT, there is shortage of the conventional radio-frequency for wireless communication. Also, VLC is one of the wireless communication technologies that uses light as a carrier instead of RF and provides wide bandwidth. So, visible light spectrum is also regarded as one of the alternative sources of RF. Further, VLC is considered economical, and secure for IoT applications. Therefore, VLC can be used for internet of things services. Furthermore, web of things (WoT) is a refinement of the IoT in which smart things are integrated on web through web addresses. So, the integration of VLC and the web of things for communication is the purpose of this paper. In this paper, VLC system is proposed for web of things applications where user can manage and monitor the web of things through web interface using visible light frequency band. The proposed VLC system is analyzed for SNR distribution throughout the given dimension of the room at different values of FOV using MATLAB simulation.

Keywords: Visible Light Communication (VLC), Web of Things (WoT), Radio Frequency (RF), Field of View (FOV)

I. Introduction

Initially, light is predicted as one of the technologies to convey information to the objects around it and named as visible light communication (VLC). Further, IEEE 802.15.7 standard defined VLC as wireless communication method for Internet of things environment. Also, VLC doesn't require a license for light visible spectrum (375-780nm) to employ communication. Furthermore, VLC system has high security, low power consumption and also other advantages [1]. Due to the wide bandwidth of visible light spectrum, the data transmission rate is high in VLC system. So, visible VLC system is regarded as "last mile" solution in the future [19].

A number of wireless access technologies are developed to provide Internet-of-Things (IoT) services like Bluetooth, Wi-Fi, Zigbee, and Near Field Communication (NFC). Most of those access technologies use the same frequency band that is either 2.4 GHz or 5GHz and thus, suffered from RF interferences. So, the performances of the system are degraded because of frequent collisions occur through interference during communications. While VLC communication is different from RF wireless access technology since it uses light for communication. So, the problem of RF interferences from numerous wireless channels can be reduced with the help VLC [19]. Also, the VLC can provide information of exact location than Wi-Fi because of particular LED light. So, this will be helpful for a variety of location based IoT services. Further, there is the seamless connection of physical devices to the internet by using emerging technology IoT. So, there is need of higher bandwidth for the generation of big data IoT system and it can be fulfilled by VLC wireless technology which provides bandwidth in terms of Giga hertz [15].

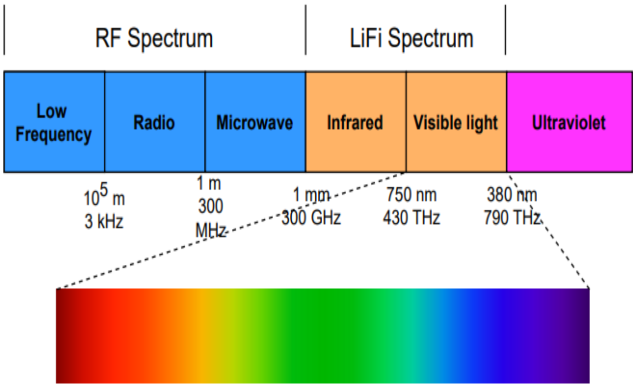

Fig. 1: Frequency spectrum

The IoT has so many proprietary and domain specific protocol stacks which is concerned with lower level of OSI stack related to hardware devices, physical layers, and connections. Also, the IoT has no specific universal application protocol to interface with different networking devices. So, there will be a need for a single universal application layer protocol to talk with devices and applications and thus make the IoT reality. The effective one idea is to reuse something which is already mostly used to build scalable and interactive applications like web. Another logical step is the use of web ecosystem and infrastructure for IoT based applications, overcoming this ongoing "one device, one protocol, one app" pattern. Hence, this gives rise to the concept of the web of things (WoT) and extends the IoT with concept of web as an open IoT ecosystem which is based on open standards. Where, the WoT concerns only top OSI application layer that manages applications, services, and data. WoT describes a set of standards by the World Wide Web consortium (W3C) for the interoperability of different internet of things (IoT) platforms and application domains. The main goal of the WoT is to standardize the use of web technologies which are already in used to build applications and web services for the IoT to make data and services offered by smart objects more accessible to every web user and developer. The implementation of the WoT concept expands access and current IoT achieves uniform functionality among smart objects such as smart Home, Industrial, smart City, Retail, and Health applications [17] [18].

The adaptation of the experience and knowledge acquired from the web into the internet of things ecosystems is Web of things. Smart things are integrated on the web and users can access smart things through web interfaces using web addresses. So, integration of VLC system for WoT applications would be great. Also, there is no such research done for these two technologies which can overcome the problem of IoT RF technologies performance.

The main objective of this paper is to analyze the VLC system performance for web of things. The performance of the proposed VLC system is analyzed for SNR distribution throughout the given dimension of room at different value of transmitter field of view.

Initially, the VLC system along with its challenges and applications was studied in detail [1]. After that, the visible light communication system was compared with others communication technologies in indoor environment in terms of data rate, bandwidth density, cost, etc. [2]. Further, the analysis of visible light positioning system by using unique ID codes to identify user's position and considering coarse location environments was proposed in [12]. Then after that, the other works for visible light communication related to channel capacity for random receivers were analyzed by varying different parameters such as light intensity, transmitter height, etc. [3]. In this way, the fundamental study of visible light communication was done.

The hybrid RF and VLC systems were proposed in [6] in which multiple VLC and RF access points were designed and the system performance was compared. In this paper, the improvement was analyzed per user average and outage throughput after the introduction of the VLC system. Hence, VLC can be used as an alternative to the RF system.

In the paper [10], IoT was implemented using the IoT protocol stack with visible light communication as the physical medium with consideration of error model. The throughput of proposed IoT implementation using light over wireless fidelity was simulated using NS3 in the paper. Also, different studies were done for the internet of things using VLC communication system [11]. Further, the devices were monitored and controlled using VLC system through web experimentally [8]. Also, the study of IoT using Visible light communication through computer with UART was done in [16]. The web of things and the need for WoT instead of internet of things were explained in the paper [18]. Further, the different four layers of WoT was explained in [17] which were application layer of OSI.

From the above literature, there was the conclusion that VLC would be great to monitor and control for the alternatives of RF based WoT things indoor applications. So, in this paper the performance of Visible light communication is analyzed for web of things applications.

The structure of this paper is as follows: section 1 presents the introduction, literature, and the objectives of the research. After that, the VLC system is presented in section 2. Further, section 3 is the explanation of simulation model and parameters. Comparison results and comparisons of VLC system performance in terms of SNR and FOV are explained in fourth section. Finally, the last section gives the overall conclusion of the paper.

II. VLC SYSTEM

The basic blocks of the VLC system use LEDs as the optical source, a visible light channel as the medium, and a Photodetector at the receiver in figure 2. The On and off keying (OOK) intensity modulation/direct detection (IM/DD) is considered in this VLC system. The output of received signal PD ($y(t)$) is given by:

$$y(t) = R\,[h_{ch}(t) * x(t)] + n(t) \qquad (1)$$

Where $x(t)$ is the optical signal, $h_{ch}(t)$ is the channel impulse response, R is the responsivity of the PD in amperes per watt, * is the convolution operator and $n(t)$ is the additive white Gaussian noise.

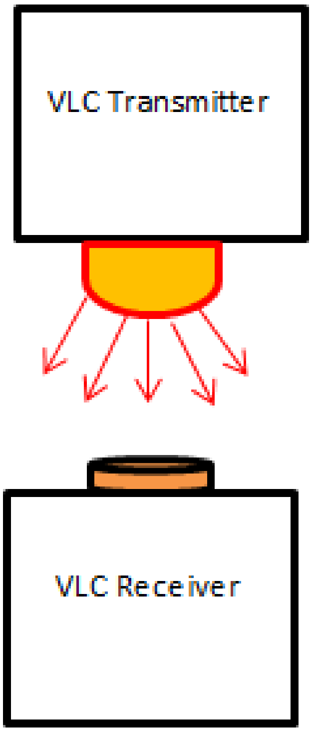

Fig. 2: Basic block diagram of VLC system

Also, $h_{ch}(t)$ is defined in terms of the LOS impulse responses of $h_{los}(t)$ i.e.

$$h_{ch}(t) = h_{los}(t) \qquad (2)$$

In this paper, VLC system is analyzed for directed line of sight (LOS) for WoT.

III. SIMULATION MODEL AND PARAMETERS

A LOS VLC system model with single transmitter and single receiver is adopted in this paper as shown in figure 3. The simulation parameters are given in Table 1, which are almost adopted from [20]. The effects of changing the TX_FOV of the LED on the SNR are analyzed. Also, the proposed system is simulated in MATLAB which is explained in figure 3.

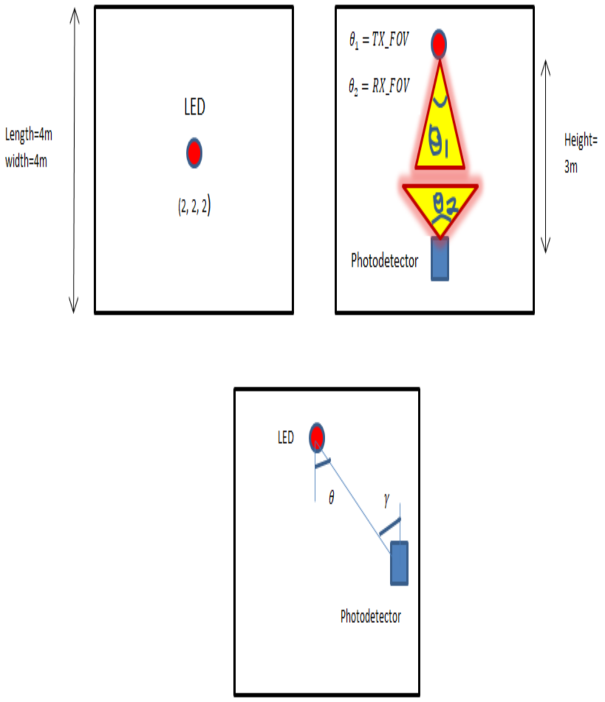

Fig. 3: Proposed simulation model

TABLE I: SYSTEM PARAMETERS

S.NO	Parameter	value
1.	Transmitter Field of View (TX_FOV)	70
2.	Transmitter location [X,Y,Z]	[2,2,2]
3.	Receiver Field of View (RX _FOV)	90
4.	Responsivity of photodiode (R)_	1
5	Data rate of system (R_b)	1000000
6	Amplifier current (I_{amp})	5e-12
7	Electron charge(q)	1.6e-19
8	Noise Bandwidth (B_n)	50e6
9	Noise Bandwidth factor (I_2)	0.562
10	Power Emitted by LED (PLED)	1
11	Height of LED (HLED)	1
12	Dimension of Room [Length, Breadth, Height)	[4m,4m,5m]
13	Distance between LED and Photodiode (height difference)	3m
14	Incidence	70π/180

The impulse response for LOS is given by:

$$h_{los} = \frac{(m+1)A_r \cos^m(\theta) cos(\gamma) T_s(\gamma) g(\gamma)}{2\pi d^2} \qquad (3)$$

where m is Lambertian order, c is the speed of the light (3 x 108 m/s) and $T_s(\gamma)g(\gamma)$are the gains of the non-imaging optical concentrator and the optical low pass filter, respectively, d is the distance between the transmitter and the receiver, Ar is the effective area of the PD, θ is the angle of irradiance with respect to the axis normal to the transmitter surface and γ is the angle of incidence with respect to the axis normal to the receiver surface. Also, θ, γ, and d is calculated by using Pythagoras theorem using dimension of the room length, breadth, and height (LED, Photodetector).

Also, the Lambertian order m is given by:

$$m = -log(2)/log(cos(Tx\_FOV) \qquad (4)$$

Where,

Tx_FOV= TX_FOV$* \pi/180$

While, g(y) is calculated by using given equation:

$$g(\gamma) = \frac{n^2}{\sin^2(RX\_FOV)} \qquad (5)$$

And $T_s(\gamma) = 1$

After defining the different parameters which is shown in table 1, the calculation for SNR is explained below:

$$SNR = \frac{(RP_r)^2}{\sigma^2{}_{shot} + \sigma^2{}_{amp}} \qquad (6)$$

Where

$$P_r = h_{los} PLED \qquad (7)$$

Now, Calculation of Noise $(\sigma^2{}_{shot}, \sigma^2{}_{amp})$

$$i.) \quad \sigma^2{}_{shot} = 2q p_{total} B_s \qquad (8)$$

Where

$$Bs = Rb * I2 \qquad (9)$$

$$Pn = Iamp/Rb \qquad (10)$$

$$p_{total} = Prx + Pn \qquad (11)$$

$$ii.) \quad \sigma^2{}_{amp} = Iamp^2 * Bn \qquad (12)$$

Finally, SNR of VLC system is calculated using all these formulas which are shown from equation (1) to equation (12) and system parameters. Also, the parameters selected are adopted according to paper [20].

IV. SIMULATED RESULTS AND DISCUSSIONS

After the simulation of system using MATLAB software, the SNR distribution is found at different values of transmitter field of view (TX_FOV) as shown in figure 4, 5 & 6.

The result had shown very good SNR throughout the room at low value of FOV. Also, found that VLC channel can be used for web of things at transmitter field of view (TX_FOV) 50 & 70 while WoT is not suitable at TX_FOV 90.

V. CONCLUSION

The VLC system is designed in MATLAB software by considering different parameters of the system such as bit rate, FOV, channel data rate, height, etc. The simulated results of VLC system are analyzed with different value of transmitter field of view for WoT applications and found that the proposed VLC system will be suitable for web of things at lower value of transmitter FOV (TX_FOV) i.e., 50 and 70 while not suitable for TX_FOV 90 since SNR is lower than 20dB for 90 TX_FOV. Finally, it is concluded that the VLC system is compatible for web of things in this work using narrow TX_FOV.

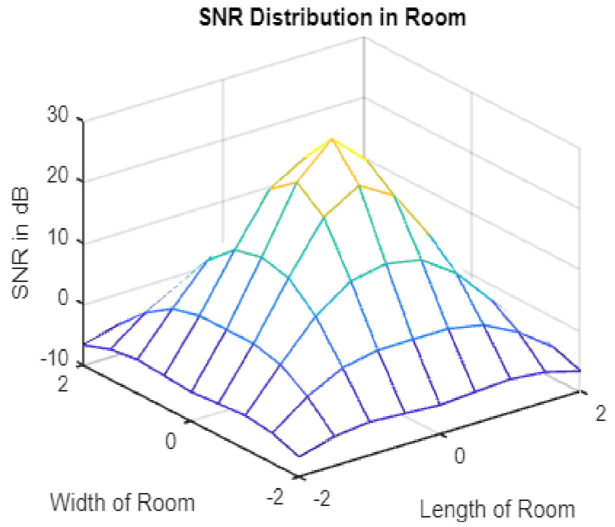

Fig. 4: SNR distribution of room at 70 TX_ FOV

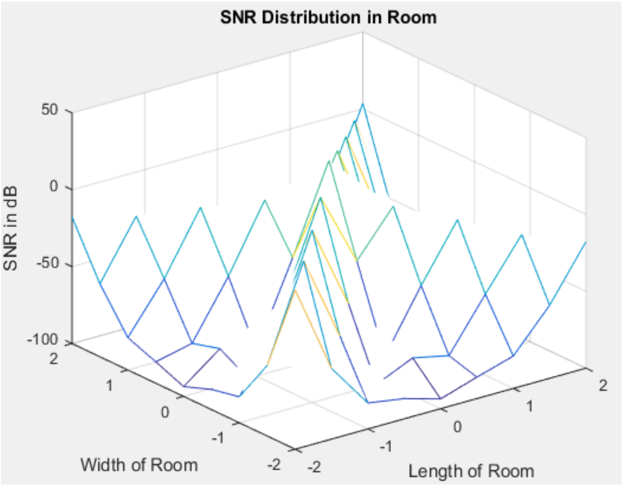

Fig. 5: SNR distribution of room at 90 TX_FOV

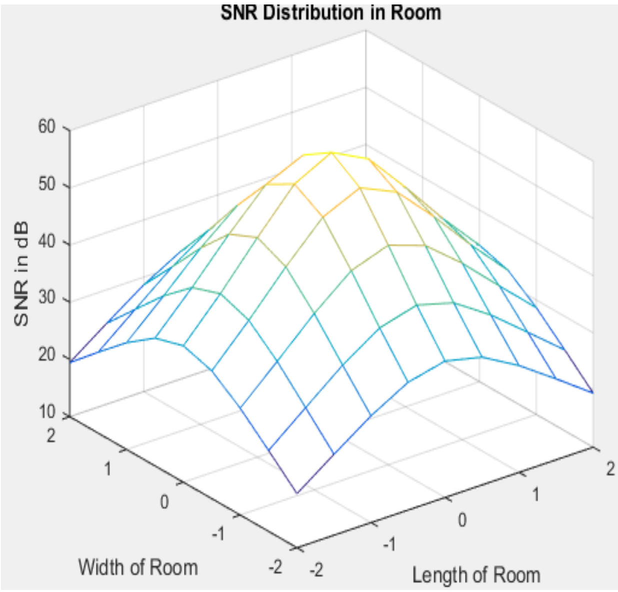

Fig. 6: SNR distribution of room at 50 TX_ FOV

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