Design of Multi-nodal Li-Fi systems

Chiranjeevi N, Aditya Shankar Hegde, Ravishankar Holla

Abstract*: *Now-a-days, the RF spectrum is used for most of the applications and automation. This is leading to the inadequacy of the RF spectrum for the human and machine requirements. As a solution to this crisis, we have proposed the use of Li-Fi (Light-Fidelity) as an alternate mode of communication. Wireless communication inside buildings and indoors is an important part of the next generation wireless communication system and these concepts can be applied to external wireless communication. Li-Fi provides high data rate (Up to 10 Gbps), improved security and high capacity to support more users. The spectrum bandwidth of light is very large, resulting in accommodation of more number users. A hybrid model of Wi-Fi and Li-Fi increases the advantages and applications, resulting in the best of both communication techniques. This paper describes the hardware implementation of Li-Fi based on IR transmitter and receiver and gives an overview of the signal conditioning for the implementation of a Li-Fi based system. This is followed by the simulation of a Multi nodal Li-Fi based system in MATLAB for determining the coverage, received power, SNR and output signal. With half angle as the variable, the coverage of an entire Multi nodal Li-Fi based system along with signal strength and other parameters can be determined. It also proposes a machine learning algorithm for selecting the best channel by considering factors like the received power, varying noise, etc.

Keywords: Li-Fi, Li-Fi hardware model, Signal Conditioning, Multi-nodal Li-Fi simulation, SNR, MATLAB, Channel selection, Machine Learning.

I. INTRODUCTION

Li-Fi stands for Light-Fidelity which is a recent technology in the field of optical wireless communication. It works on the principle that uses light to transmit data. This light emitted can be received by the respective photo-receptors for communication. It works on the line-of-sight communication. Different modulation techniques can be implemented to a Li-Fi system for achieving higher speed.

Due to the increasing demand for wireless data communication, the available radio spectrum below 10 GHz (cm wave communication) has become insufficient [1]. Li-Fi technology is proven to have higher data rates up to 10 Gbps and an increased spectrum that can be utilized for its operation. The conventional parameters, such as amplitude and phase, cannot be modulated in case of light. So, in VLC, the signal is modulated in terms of the intensity variations, which is not possible in RF.

Light cannot pass through opaque objects like walls, furniture, etc. So compared to the existing Wi-Fi, it is less vulnerable to the external attack. As it is confined to a region, Li-Fi is more secure.

II. LITERATURE SURVEY

Due to the increasing demand for wireless data communication, the available radio spectrum below 10 GHz (cm wave communication) has become insufficient. Light-fidelity (Li-Fi) is a continuation of the trend to move to higher frequencies in the electromagnetic spectrum. Like any other wireless communication technique, one can implement various modulation scheme such as single carrier, multi carrier modulation based on the application [1]. In a Li-Fi system, selection of transmitter and receiver plays an important role. LED based systems are simple, but light emitted from LED diverges in the ambient lighting conditions [3]. So, Laser and Infrared based transmitter and receiver techniques act as better alternative.

When there are multiple transmitters, the receiver has to select the best channel [4]. There are various channel estimation techniques available for selecting the best channel. BER in the MMES (Minimum mean square error) technique was better compared to that of LS (Least square) [5]. Thus, selection of the learning model is dependents on various requirements such as accuracy of channel, complexity of the algorithm etc.

In the upcoming section of the paper, the design and working of the hardware architecture is explained along with the MATLAB simulation of the multi-nodal Li-Fi system. The detailed explanations and results of each of the modules are clearly shown in the upcoming sections.

III. WORKING

The working consists of a hardware implementation of a Li-Fi system to transmit data through infrared light, followed by the simulation of a multi-nodal system to obtain a graphical representation and plots of the signal characteristics (Received power, SNR etc.) at a particular region in MATLAB and then followed by a machine learning algorithm to select the best node based on received power and varying noise in real-time

A. Hardware design

Real time audio signal from the mobile phone is given to the IR transmitter. The IR receiver captures the intensity variations, these variations are processed and fed to the speaker. The transmitted audio signal from the phone is audible at the receiver.

Revised Manuscript Received on June 22, 2020.

Chiranjeevi N, Department of Electronics and Communication, R.V College of Engineering, Bengaluru, India E-mail: naraharichiranjeevi@gmail.com

Aditya Shankar Hegde, Department of Electronics and Communication, R.V College of Engineering, Bengaluru, India E-mail: adityashankar1998.abli@gmail.com

Ravi Shankar Holla, Assistant Professor, Department of Electronics and Communication, R.V College of Engineering, Bengaluru, India E-mail: ravishankarholla@rvce.edu.in

Tx Side: An Infrared transmitter is used in the transmitter section to transmit the signal. An audio signal is given from the phone as input to the transmitter. A resistance of 1 kΩ is used in series with the IR LED to limit the current. The LED changes its intensity with respect to the audio signal from the phone. This change is captured by the IR receiver.

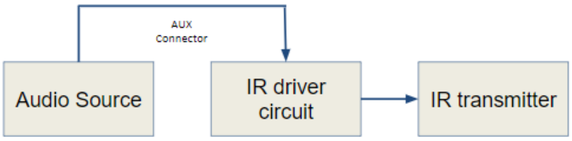

Fig. 1. Transmitter side block

Rx Side: IR receiver detects the change of IR LED, switching its own states. As the IR LED conducts and gives the output according to the dc voltage of 5 V. A non-inverting amplifier is used to amplify the signal and a resistor-capacitor filter is used to filter the signal to reduce noise. After an interfacing phase of circuitry, it is fed to the aux cable for the output. The output is observed through a speaker and the input signal is replicated.

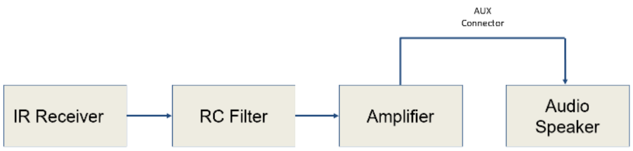

Fig. 2. Receiver side block

B. Multi-nodal simulation in MATLAB

A Li-Fi system with multiple sources is simulated in MATLAB. By considering a light source, based on the equations of the radiation intensity, channel gain, power received, a simulation model is built for multiple sources. The angle of incidence is taken as a variable from which the area of coverage of each individual light source is found out. As the angle of incidence increases, the area of coverage of each light source increases. For the illumination intensity at any point on the 3D plane, Lambertz rule is used which relates the radiation intensity at any point with the angle of radiation as shown in (1).

$$R = R_0 \cos^m \phi \qquad (1)$$

Where,

R= Radiant Intensity

m = 0, for isotropic source

Φ = angle of incidence

For a given channel in the multi node LiFi the received signal can be expressed by the Equation 2. The simulation is done by considering channel gain as (3).

$$Y = HX + N \qquad (2)$$

Where,

H = Channel gain

N = Normally distributed noise

$$H_{LOS} = \frac{A_{rx}}{d^2} R(\phi)\cos(\Psi) \qquad (3)$$

Where,

A_{rx} = Area of the receiver

d = Distance from the source

$R(\phi)$= Radiant intensity

Ψ = Angle of incidence

The received power at the LOS can be determined by (4).

$$P_r = P_{LED} \times R(\phi) \qquad (4)$$

Where,

P_{LED} = Power emitted at the LED source

Based on these equations LED coverage, received power, channel response and SNR are plotted by considering normally distributed noise. From the simulation of a multi-nodal Li-Fi system, the exact power from the source can be determined at the given point. The area of coverage for the given node can be determined and the region of operation (where optimum signal is obtained) can be determined.

C. Channel estimation and Machine learning

Multiple transmitter conditions will create multiple Li-Fi channels. Under different noisy (background light) conditions the received channel characteristics will also change. So, the receiver is trained under different conditions so that it will be able to model a single channel response based on the learning. From the previous learning, the noise can be minimised. Figure 3 shows the block diagram of the neural network-based channel estimator

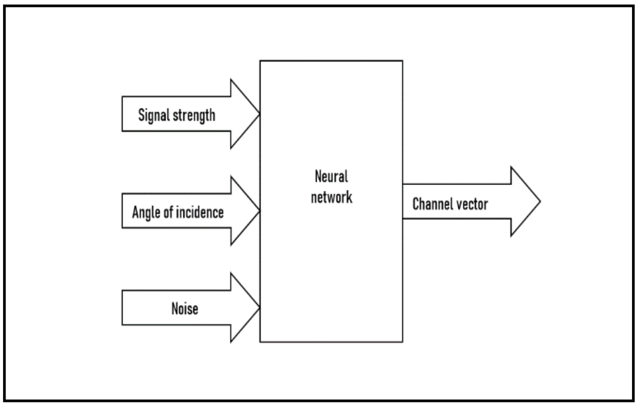

Fig. 3. Block diagram of proposed LiFi channel estimation

Signal strength, Angle of incidence and noise were the major parameter considered as inputs to the neural network. By considering the inputs, the neural network is trained to select best channel. The channel vector is obtained as the output of the training. During the process of training, the channel vector acts as variable weights and varies with respect to different inputs. Using the channel vector, the best available node is selected in a multi nodal Li-Fi system. Figure 4 shows the representation of a two layered neural network with one active function for channel estimation [6].

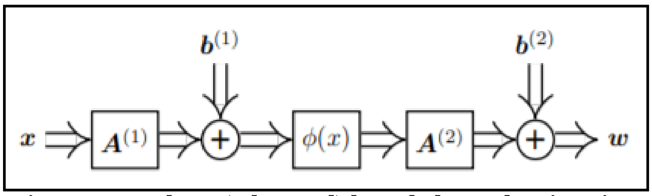

Fig. 4. Neural net (2 layered) based channel estimation with one active function.

IV. RESULTS

A working model of Li-Fi is demonstrated by taking audio input from the smartphone and sending this analog signal through the IR transmitter and receiver which is connected to an output speaker as shown in figure 2.

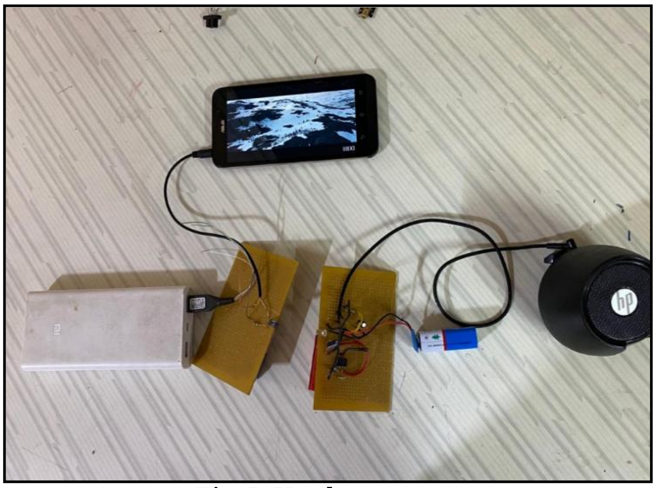

Fig. 5. Hardware setup

Multi source Li-Fi is simulated with four transmitting nodes (LEDs) considering half angle as 8.75^0. Figure 6 shows the top view of the LED coverage.

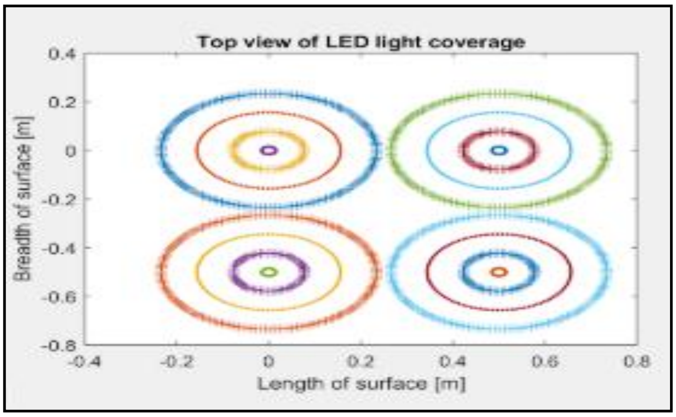

Fig. 6. Top view of LED light coverage

The received power in dB was plotted for the similar condition as shown in Figure 7. Figure 8 is the channel response and the Figure 9 is the distribution of SNR at the receiver by considering AWGN.

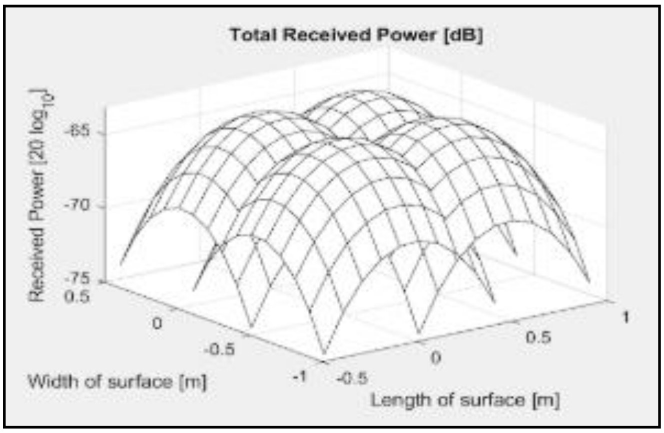

Fig. 7. Total received power

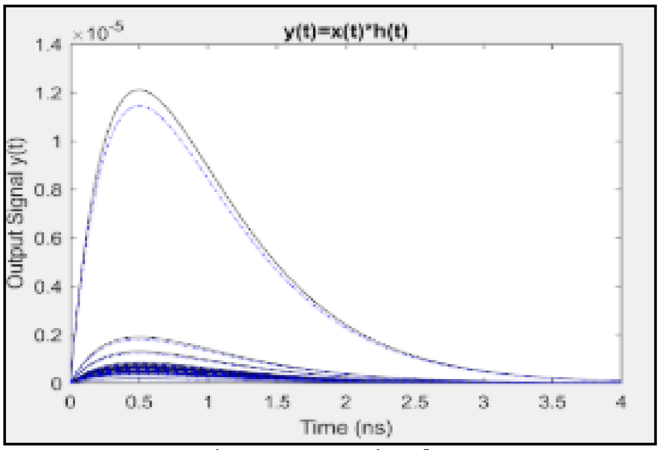

Fig. 8. Output signal

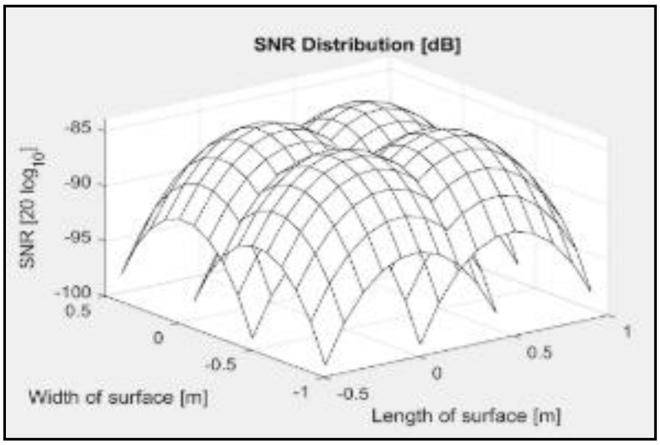

Fig. 9. SNR distribution

V. CONCLUSION

This paper presents a detailed hardware implementation of Li-Fi based on Infrared transmitter and receiver. Considering Single and multiple light sources the radiation pattern, coverage, received power, Signal to Noise ratio were simulated for different incidence angle using MATLAB. For denoising of the signal under ambient light conditions and selection of the best channel under multiple transmitter condition, a learning model were proposed to select the best available channel.

Light Fidelity is an emerging technology which has a lot of potential in revolutionizing the communication industry. Li-Fi nodes can be used as a source of light as well as a node for communication. This technology has its own advantages and disadvantages. While providing higher speeds, security and huge bandwidth, it is confined within opaque objects. A hybrid model consisting of both Wi-Fi and Li-Fi nodes presents best of both the technologies and revolutionizes the way we communicate with the world.

REFERENCES

1. H. Haas, L. Yin, Y. Wang and C. Chen, "What is LiFi?," in Journal of Lightwave Technology IEEE, vol. 34, no. 6, pp. 1533-1544, 15 March 15, 2016
2. S. Kulkarni, A. Darekar and P. Joshi, "A survey on Li-Fi technology," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET) IEEE, Chennai, 2016, pp. 1624-1625.
3. S. Dimitrov and H. Haas, Principles of LED Light Communications: Towards Networked Li-Fi. Cambridge, U.K.: Cambridge Univ. Press, Mar. 2015.
4. X. Wu, M. Safari and H. Haas, "Access Point Selection for Hybrid Li-Fi and Wi-Fi Networks," in IEEE Transactions on Communications, vol. 65, no. 12, pp. 5375-5385, Dec. 2017.
5. Yaseein Soubhi Hussein and Amresh Chetty Annan, "Li-Fi Technology: High data transmission securely",IOP Conf. Series: Journal of Physics: Conf. Series 1228 (2019) 012069.
6. D. Neumann, T. Wiese and W. Utschick, "Learning the MMSE Channel Estimator," in *IEEE Transactions on Signal Processing*, vol. 66, no. 11, pp. 2905-2917, 1 June1, 2018, doi: 10.1109/TSP.2018.2799164
7. T. D. C. Little, P. Dib, K. Shah, N. Barraford, and B. Gallagher. "Using LED Lighting for Ubiquitous Indoor Wireless Networking". IEEE International Conference on Wireless & Mobile Computing, Networking & Communication, pp. 373-378, 12-14 Oct 2008
8. T. Komine and M. Nakagawa. "Fundamental Analysis for Visible-Light Communication System using LED Lights". IEEE Trans. on Consumer Electronics, vol. 50, no. 1, pp. 100-107, 2004
9. S. Rajagopal, R. Roberts, and S.-K. Lim, "IEEE 802.15.7 visible light communication: Modulation schemes and dimming support," IEEE Commun. Mag., vol. 50, no. 3, pp. 72–82, Mar. 2012.
10. D. Tsonev, H. Chun, S. Rajbhandari, J. McKendry, S. Videv, E. Gu, M. Haji, S. Watson, A. Kelly, G. Faulkner, M. Dawson, H. Haas, and D. O'Brien, "A 3-Gb/s single-LED OFDM-based wireless VLC link using a gallium nitride µLED," IEEE Photon. Technol. Lett., vol. 26, no. 7, pp. 637–640, Apr. 2014.
11. D. A. Basnayaka and H. Haas, "Hybrid RF and VLC systems: Improving user data rate performance of VLC Systems," in Proc. IEEE 81st Veh. Technol. Conf. (VTC Spring), Glasgow, U.K., May 2015, pp. 1–5
12. Z. Chen, N. Serafimovski, and H. Haas, "Angle diversity for an indoor cellular visible light communication system," presented at the Vehicular Technology Conf., Seoul, Korea, May 18–21, 2014
13. E. Sarbazi, M. Uysal, M. Abdallah, and K. Qaraqe, "Ray tracing-based channel modeling for visible light communications," in Proc. 22nd Signal Process. Commun. Appl. Conf., Apr. 2014, pp. 702–705
14. Ahn, K.-I & Kwon, Jae Kyun. (2012). Color Intensity Modulation for Multicolored Visible Light Communications. Photonics Technology Letters, IEEE. 24. 2254-2257. 10.1109/LPT.2012.2226570
15. Y. Wang, X. Wu, and H. Haas, "Distributed load balancing for Internet of Things by using Li-Fi and RF hybrid network," in Proc. IEEE 26th Annu. Int. Symp. Pers., Indoor, Mobile Radio Commun. (PIMRC), Hong Kong, Aug./Sep. 2015, pp. 1289–1294.
16. X. Li, R. Zhang, and L. Hanzo, "Cooperative load balancing in hybrid visible light communications and WiFi," IEEE Trans. Commun., vol. 63, no. 4, pp. 1319–1329, Apr. 2015.
17. L. A. Zadeh, "Fuzzy sets," Inf. Control, vol. 8, no. 3, pp. 338–353, Jun. 1965. [14] H. Burchardt, S. Sinanovic, Z. Bharucha, and H. Haas, "Distributed and autonomous resource and power allocation for wireless networks," IEEE Trans. Commun., vol. 61, no. 7, pp. 2758–2771, Jul. 2013.
18. E. Perahia and R. Stacey, Next Generation Wireless LANs: 802.11n and 802.11ac. Cambridge, U.K.: Cambridge Univ. Press, 2013
19. Z. Chen, D. Tsonev, and H. Haas, "A novel double-source cell configuration for indoor optical attocell networks," presented at the Global Telecommunication Conf., Austin, TX, USA, Dec. 8–12, 2014.
20. S. Rajbhandari, H. Chun, G. Faulkner, K. Cameron, A. V. N. Jalajakumari, R. Henderson, D. Tsonev, M. Ijaz, Z. Chen, H. Haas, E. Xie, J. J. D. McKendry, J. Herrnsdorf, E. Gu, M. D. Dawson, and D. O'Brien, IEEE Proof 12 JOURNAL OF LIGHTWAVE TECHNOLOGY "High-speed integrated visible light communication system: Device constraints and design considerations," IEEE J. Sel. Areas Commun., vol. 33, no. 9, pp. 1750–1757, Sep. 2015.

AUTHORS PROFILE

Mr. Chiranjeevi N is pursuing his Bachelor of Engineering in Electronics and Communication from R V College of Engineering, Bangalore, India. His interests include programming, embedded systems, machine learning, communication, networking and Analog & Digital circuit design. He has done internships in various organizations like Baxter Innovations and Business Solutions, Robert Bosch Engineering and Business Solutions and Pragun Powertronics and Automation. He is also the 'Electronics lead' at Team Chimera, which is a student formula electric team. He has participated and won in many student formula electric events in the national level. He has also collaborated with startups like Dextrose Technologies and completed projects in different domains.

Mr. Aditya Shankar Hegde is pursuing his Bachelor of Engineering in Electronics and Communication from RV College of Engineering, Bangalore, India. His interests include Analog and Digital circuit design, Machine learning, Communication and networking. He has done internship program in Baxter Innovations and Business solutions on Power electronics. He has worked on Network on chip project and published one conference paper on that. He has also worked on Machine learning projects in Deep-hive (a startup company).

Mr. Ravishankar Holla is working as an Assistant professor in the department of Electronics and Communication Engineering, Bangalore, India. He completed his B.E in Telecommunication Engineering, M.E in Computer Network Engineering and is currently pursuing his Ph.D. in sensors and sensor networks. His interests include Sensors and Sensor networks, Embedded Systems, Computer Communication Networks, communication and Machine Learning.