Survey on Li-Fi communication networks and deployment

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ABSTRACT

Light Fidelity (Li-Fi) is a technology in the field of Visible Light Communications (VLC) that renders transmission of data via illumination by sending data through a Light Emitting Diode (LED) light bulb. This technology uses a photo-detector to receive light signals and a signal processing element to change over the information into a stream-capable substance. Out of this survey paper, we see that Li-Fi technology execution and research has been carried out in patient monitoring systems, vehicle toll gate systems, under roof blind navigation systems and other applications. Limited research has been carried out on Li-Fi communication networks and deployment. Nonetheless, there is a lot of potential to implement it. This includes many applications in sensitive electromagnetic interference environments such as air crafts and power plants where Wireless Fidelity (Wi-Fi) is not suitable but fast and interconnected data systems are still required. Li-Fi has potential in areas where secure networks are required and where there is need to track signal availability and transmission radius as in banks and intelligence gatherings like in the military and government special operations. It can also provide high data capacity in heavily populated environments such as colleges, malls and conference centers. There are still unattended scopes like Li-Fi network integration with the mobile network and the optical fiber network. No guidelines have been developed for the efficient deployment of Li-Fi networks to suit different applications such as hospitals, clinics and banks.

Keywords: Access point (AP), light emitting diode (LED), light fidelity (Li-Fi), line of sight (LoS), modulator demodulator (MODEM), radio frequency (RF), visible light communications (VLC), wireless fidelity (Wi-Fi).

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INTRODUCTION

Li-Fi is a fast wireless communication technology that utilises visible light. It is considered as Wi-Fi that is dependent on light (Shah et al., 2017; Lu et al., 2017). It falls under the category of optical wireless communications (Zhu et al., 2015). Li-Fi uses LED transceiver lamps that can be used to provide light for a room, and transmit and receive information (Kulkarni et al., 2016). The LED light power changes and based on this variation, communication occurs digitally. Li-Fi came into existence in year 2011 Coined by a group of scientists Prof. Harald Haas, Dr. Mostafa Afgani and Dr. Gordon Povey, at Edinburgh University in the United Kingdom. They started their exploration in 2004. This innovative approach utilises a part of the electro-magnetic spectrum that is as yet not significantly used, the spectrum of Visible Light. The Visible light spectrum covers wavelengths from 375 to 780 nm (Ezhilazhagan et al., 2017). The VLC spectrum has 10000 times more space than the Radio Frequency (RF) spectrum (Haas, 2017). By changing the speed at which LEDs flash on and off to give different strings of 1s and 0s, it is possible to encode information in the light. The LED intensity changes so rapidly that human eyes cannot perceive the change, which is why the output seems constant.

Li-Fi innovation has vast advantages contrasted with Wi-Fi. It takes out the adverse wellbeing impacts of using electromagnetic waves because it does not interfere with any electronic circuitry and is therefore safe and non-hazardous (Cailean et al., 2018). Given that light cannot pass through solid objects and walls, confidential information can be kept in an enclosed area (Wang et al., 2014). Li-Fi is also 1000 times denser than Wi-Fi. This is attributed to less light interference than radio interference. The output speed is also very high because

of high data density and bandwidth. As a result of these advantages, this technology is attractive for implementation in hospitals, clinics, banks and many more. There is an uncountable number of light bulbs worldwide which can be reestablished with LEDs for actual transmission of information, so availability is not an issue. This paper, therefore, further surveys implementations done with Li-Fi, challenges and further open areas.

HOW LI-FI WORKS

Li-Fi technology is based on the VLC system that uses visible light ranging from 400 THz (780 nm) to 800 THz (375 nm) as the optical carrier for data transmission (https://seminarsprojects.net/Thread-li-fi-light-fidelity-the-future-technology-in-wireless-communication; Haas, 2017). The team working on visible light connectivity 802.15.7 specification concluded the physical layer (PHY) project implementation and Media Access Control (MAC) for VLC in December 2011 (Gavrincea et al., 2014; I. Standard and I. C. Society, 2011). Li-Fi is installed on the downlink transmitter using white LED light bulbs. These devices are usually used for lighting using a constant current (Sarkar et al., 2015). Nevertheless, the optical quality can be varied at incredible speeds by small but rapid current variations. This optical current principle is used in Li-Fi wireless communication (Prakash and Agarwal, 2014). Data transmission is made possible by the invisible on-off action using binary codes. When an LED is switched on, a binary '1' is transmitted to a photo receiver and switching it off transmits a binary '0' to a photo receiver as shown in Figure 1. By changing the speed at which LEDs come on and off to produce different strings of 1s and 0s, information can be encrypted in the light. Modulation is too fast for humans to see (Sarkar et al., 2015). Using elevated speed, LEDs with sufficient multiplexing can attain data rates of more than 100 Mbps. The data rate of the VLC can be increased by parallel data transmission of LED arrays with each LED transmitting a different data stream (Karthika and Balakrishnan, 2015).

Figure 2 shows that data coming from the internet goes in to the Modulator-Demodulator (MODEM) where necessary modulation takes place. Once modulated, the information is then fed to the LED driver where driving current changes with the incoming streaming data. When the optical data is received, it is first changed in to an electrical signal using a photo detector at the receiving end. After signal conditioning (amplification, processing and retrieval of binary data) data is fed in to a laptop or other web empowered gadgets.

LITERATURE REVIEW

Ezhilazhagan et al. (2017), Sudha et al. (2016), Pravin

Figure 1. Basic principle of VLC (Mamidkar and Samantray, 2018).
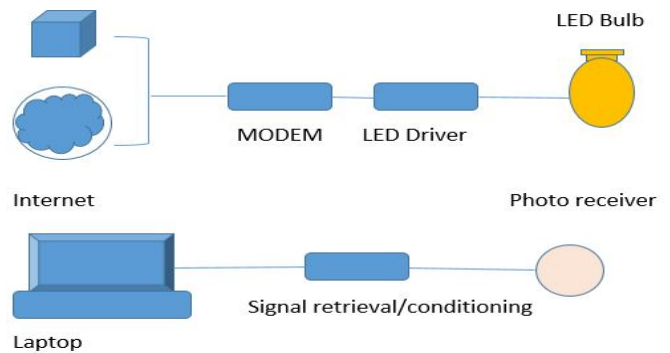
Figure 2. Block diagram showing working principle of Li-Fi (Kulkarni et al., 2016).

and Sundararajan (2018) and Palanivel and Chen (2018) proposed models for uses of Li-Fi technology in various frameworks. The crisis of congested RF band which ranges from interference, limited transfer speed to fear for human wellbeing, has prompted investigation of Li-Fi as an efficient wireless communication alternative in these applications. Li-Fi is preferred because of its various focal points over Wi-Fi innovation. The models use PIC microcontrollers as the intelligent processor and have a data transmitter (LED Light) and a data receiver (Photodetector) empowering a working Li-Fi system. Parameters such as ON-OFF speed and the number of LEDs influence the communication speed. On the off chance of quick ON-OFF LED frequency, information can be conveyed as 1's and 0's at high rates. Higher amounts of LED's in a network contribute to more information being transmitted at a time. Sudha et al. (2016) introduced a prototype of a model that helps in patient monitoring in hospitals using Li-Fi rather than Wi-Fi innovation to stop radio frequency contact with the human body and the medical equipment. In this model, sensors for temperature, heartbeat, glucose and respiration are used to gather information from the human body. In the PIC16F877A microcontroller, the collected data is converted to electronic format using analog to digital converter. The microcontroller's output is then loaded in to the Li-Fi module which sends the data

in light form. The photo detector senses the light at the receiver end. The information obtained is then shown as a chart on a screen connected to the receiver end using Universal Asynchronous Receiver/Transmitter (UART) to analyze the patients' health. The report on the health of the patient is then automatically sent to the person concerned through the internet.

In Singh et al. (2017), a design of a prototype of a system that transmits user information from a vehicle to a toll using the power of Li-Fi wireless communication is introduced. The transmitter circuit is operated by the 12V battery of the vehicle which powers its electronic components. A microcontroller and a memory is installed in every vehicle and a setup is used to submit useful encoded data like vehicle number, personal identification number and payment gateway password via LED. The Li-Fi receiver is installed at the tollbooth in the center of the road. The trans-impedance amplifier amplifies the signal as it travels from the transmitter to the receiver. An intelligent processor (microcontroller) at the receiver side automatically processes the tax payment of the toll according to the type of vehicle via a wallet associated with vehicle number and sends users confirmation of the toll deduction by SMS. At the sender side, cloud is also interfaced to get notification in a mobile application and to save the data history.

Palanivel and Chen (2018) proposed an automotive cable harness reduction system using Li-Fi technology and launched a dedicated Li-Fi receiver. The system includes a multiplexer, transmitter, de-multiplexer and a receiver. Li-Fi transmitters are implemented by manipulating a vehicle's LED light intensity, while a low-end micro-controller implements the Li-Fi multiplex or de-multiplex. The proposed design of the Li-Fi receiver comprises two components, a photo detector and a trans-impedance amplifier (TIA). Measurements of different distances between the Li-Fi transmitter and the proposed Li-Fi receiver were successfully carried out in and outside a vehicle. To monitor and interpret the received information, the output of the proposed obtained signal was examined and demonstrated on the oscilloscope. Measurement results showed that the proposed Li-Fi receiver absorbs and transforms light signals successfully. This approach has been successfully deployed to replace the wiper, fan assembly and lamp wiring harness in vehicles, thereby reducing the weight by 400 g.

In Pravin and Sundararajan (2018), VLC based indoor blind navigation system is presented. Because of the benefits of electromagnetic noise resistance and precision, VLC-assisted indoor positioning is intended to provide guidance for blind people instead of traditional wireless positioning solutions which use radio frequency equipment. The positioning mechanism is supported by a range of fixed transmitters and a moving receiver. The transmitter is installed on the object or place to be identified by the blind people. A transmitter segment made up of Li-Fi transmitter, PIC microcontroller and toggle switch sends predetermined object or location data

when a moving receiver consisting of a voice playback chip, Li-Fi reader, speaker and a PIC microcontroller comes in line of sight. The data loaded into the transmitter microcontroller is delivered to the reader when the transmitter and the receiver are synchronized. This in effect activates the receiver microcontroller to evoke the appropriate audio output by changing the recorded circuit on the speaker. This in turn helps the blind to recognize the object or location in front of them.

Wang et al. (2017) introduces a VLC based Intelligent Transportation System (ITS) framework for truck fleets going through the traffic lights without slowing down through theoretical analysis and quantitative measurement approaches to determine the relationship between truck fleet velocity and traffic signal transition time. The outcome is important in constructively minimizing possible accidents caused by repeated lorry speed increase and decrease. In the experimental VLC – based infra-to-vehicle prototype system (Fang et al., 2016), the VLC transmitter is installed on the roadway intersection where it sends traffic management data in real time. The transmitter consists of a USB-to-serial-port that transforms the control signal to a serial signal, a laptop that is the source of information, an industrial white LED light and an On-Off Keying-based modulation. The VLC receiver consists of a retail PIN fitted with the detector focus element, an On-Off Keying demodulator and a low noise amplifier. The receiver is mounted on each vehicle and determines whether the smart vehicle will move straight ahead or make a turn based on the message it receives. Because of the short propagation distance of VLC technology, there is a Line of Sight (LOS) between the network system and the vehicles with reliable signal output.

Hocaoğlu et al. (2019) presents a VLC device model that is capable of transmitting music and video using cheaper sender and recipient circuitry relative to current VLC implementations. The appropriate transmit power is also calculated in order to determine application layout in practical conditions. This model is basic and reasonably low–cost compared to current models in this field, and therefore has the capacity for volume manufacturing. The video is sent from the transmitter computer and loaded in to the HDMI-AV converter which transforms the high definition video in to a composite video baseband signal as well as stereo audio signals. The signals are subsequently transferred to the modulator and emitted out via the LEDs. Light bearing the signal lands on the photodiode at the receiver end and is transformed to an electrical impulse which is interpreted by the receiver circuits. The subsequent pulse is then transferred to a capture card, the AV-USB converter. Eventually, the receiver computer interprets and displays visual data from the capture card.

Zachár et al. (2017) introduces a proposal for a beaconing network based on LEDs that can be used in interior indoor localisation applications. As part of the current lighting system, the LED beacons flash at a high

rate whereas the detectors are normal cameras. The recognition is dependent on a coding scheme that condones the signal under sampling since camera's sampling frequency is much slower. The suggested device structure consists of a segment for beacon detection, a wide angle camera and the modulated LED beacons. An LED driver modulates the light discharged by each LED and each LED transmits a specific beacon ID. The process takes place at a very high frequency enabling service without flickering. A camera is used in the detector and the picture sequence is used to identify pixels corresponding to the beacon IDs. Pixels sensed are used to locate image blobs corresponding to each beacon and the localisation method then determines the unknown position using the detection picture.

The concept of creating a virtual infrastructure using Li-Fi network and distributing resources by pooling has been proposed in paper (Dembla et al., 2018). This resource pool is regulated by an independent server that manages the grid's tasks. The server monitors different specifications such as storage capacity and computing power linked to the collective resources and activities on the network. It renders cheaper and faster speed connectivity links via Li-Fi technology, resulting in simple implementation and enhanced functionality. The designed grid focuses on the architecture of the client server. Features such as submitting tasks, contributing resources and processing grid tasks from other machines are given to users. The server transmitter and receiver set deploy Li-Fi network to interact with other devices which are also facilitated with Li-Fi connectivity. The system consists of the grid server software and the grid client software with Li-Fi based interaction connections. The program for the grid client is activated on each client PC. It is made up of the resource donation module and the job submission module. The task delivery unit ensures that the process information is transmitted to the server for implementation, whereas the resource donation unit manages the resources allocated to the grid. The grid server program comprising of applications for event management and resource management is activated on the server computer. These are equivalents of the grid server's submission system for task and resource allocation. To monitor the grid's state, MySQL database is retained on the server.

Ezhilazhagan et al. (2017) proposed a working model for shopping with automatic product sensing and smart billing using Li-Fi. The work showed that the number of small and large shopping malls has increased over the years in the world because of increased demand for goods and services. The model consists of four sections: payment and billing, product identification, trolley and the server. Product identification; Radio-Frequency Identification (RFID) tag which has details and a unique 14-digit number is attached to each product. The trolley comprises a Li-Fi transceiver, RFID reader, Liquid Crystal Display (LCD) display and a microcontroller where the remaining details of the product are kept. The reader sees all the products added in to the trolley and if one or multiple products are removed at once, such products will be deleted from the system. Li-Fi in the trolley communicates with the server Li-Fi and updates the information where necessary. The payment and billing section comprises of an android software that shows purchases, amounts, complete with discounts and the payment method. The list of all purchased goods is sent to the server which looks for offers on the products and re-sends the information to the trolley if any. Table 1 summarizes applications where Li-Fi technology has been used and the benefits of such technology.

From this literature review, we can see that Li-Fi has attracted implementation and research in hospitals, cable harness reduction in automotive, vehicle toll gate systems, indoor blind navigation systems, automatic product detection and smart shopping billing and many more applications. There are few applications where Li-Fi technology has already been deployed. Studies indicate that Li-Fi has potential for many other implementations such as dense urban environments, submarine communication, cellular communication, electromagnetic sensitive environments such as aircrafts and more.

HYBRID LI-FI AND WI-FI SYSTEM MODELS

The growing data requirements for domestic use (Kulkarni et al., 2016; Singh et al., 2017), have led to the suggestion that hybrid Li-Fi and Wi-Fi networks be used exploiting both the wide bandwidth of visible light spectrum and radio frequency transmission diffraction potential [21]. This chapter therefore discusses various architectural structures of the Hybrid Li-Fi / Wi-Fi network communication.

Li-Fi point-to-multipoint system

In Miras et al. (2018), the suggested point-to-multipoint solution for Li-Fi consists of embedded lamp and dongle modems. The real-time hardware modem is used to link the upper network (Internet, Enterprise Network) and the wireless optical connectivity to Li-Fi. This embedded lamp modem links with the network via Ethernet and provides both lighting energy and analog communication signal to the network. It operates with a wide range of LED lamps and an external driver. The USB powered embedded dongle incorporates both the visible spectrum reception down link and the upper path Infra-Red spectrum emission. It has the form factor of credit card and is powered by USB and plug-and-play.

Li-Fi indoor access model

The access architecture is made up of a collection of Li-Fi Access Points (AP) installed on the roof of the ceiling.

Table 1. Li-Fi applications and benefits.

Paper	Application	Description	Benefits	System components
Sudha et al. (2016)	Hospital management Patient monitoring	Temperature, heartbeat, glucose and respiration sensors capture data from the human body. PIC16F877A changes signals into a digital format and feeds it in to Li-Fi module which then sends the data in light form. The light is picked up at the receiver end by the photo sensor. The information received is then presented graphically on a computer.	Avoids frequency contact with the human body and medical equipment.	Glucose, Temperature, respiration and heartbeat sensors, PIC16F877A, LED lights, Li-Fi module, photo detector
Singh et al. (2017)	Vehicle Toll Collection System	The transmitter circuit is installed in every vehicle and a setup is used to send useful encrypted data such as vehicle number, personal identification number and payment gateway password via LED. The Li-Fi receiver with a photo-detector mounted in the middle of the road at tollbooth senses any variations in the light transmitted from LED. An intelligent processor at the receiver side automatically processes the payment using the type of vehicle by means of a wallet linked to the vehicle number and sends a confirmation for the toll deduction through SMS to the user.	Technology can help conserve fuel and create an environmentally friendly environment.	LED, microcontroller, photo-detector, trans-impedance amplifier
Palanivel and Chen (2018)	Wiring Harness Reduction in Automotive	Wiring Harnesses combines control and communication wires. Such a solution was successfully carried out and replaced the wiring harness for lamp, wiper and fan assembly in vehicles, this reduced the weight by 67%.	Reduction in vehicle weight and fuel consumption.	Transmitter, receiver, multiplexer, de-multiplexer, LED lights
Pravin and Sundararajan (2018)	Blind Navigation system based on VLC	When the receiver and the transmitter are aligned, information loaded in the transmitter microcontroller is forwarded to the reader. This stimulates the receiver microcontroller by switching on the voice recorded circuit and sending it through the speaker to trigger the required audio output. This helps blind people to identify obstacles or places ahead.	Providing guidance to blind people to find objects or locations in unfamiliar indoor environments	Mode switch, PIC microcontroller, voice playback chip, Li-Fi transmitter, Li-Fi reader, speaker
Ezhilazhagan et al. (2017)	Automatic product identification and intelligent shopping billing	The system has four sections: namely one that identifies products, one that serves as a trolley and a server for billing and payments. In product identification, each product is attached to an RFID tag which contains its details and a unique 14-digit ID. The Trolley consists of an LCD display, Li-Fi transceiver, a microcontroller where the remaining product details are stored and an RFID reader. The reader can detect all products added to the trolley and updates list if one or more products are removed. Li-Fi in the trolley communicates with the server Li-Fi and updates the information if needed.	Convenience when shopping. We can significantly reduce the queue or even eliminate its purpose by implementing this process.	RFID tag, Li-Fi transceiver, android application, LCD display, RFID reader, microcontroller

Table 1. Continues.

		The payment and billing section comprises an android software that displays purchases complete with discounts, amounts and the method of payment. Payment can either be online or by cash. The Server comprises a Li-Fi transceiver and a computer. The list of all purchased items is sent to the server, which checks for discounts on the items and returns the details to the trolley. The trolley is updated with new information after the payment has been made.		
Wang et al. (2017)	Smart Transportation Framework	Evaluates the relationship between the speed of the lorry fleet and the transformation time of the traffic lights. The VLC transmitter is installed on the roadway intersection. It transmits traffic management data in real time. The receiver is fixed on each vehicle and decides whether the smart vehicle will move straight ahead or make a turn depending on the message it receives.	The result is significant in proactively reducing accidents caused by repeated lorry acceleration ad deceleration.	USB-to-serial-port, laptop, industrial white LED light, On-Off Keying-based modulator, retail PIN fitted with detector focus element, On-Off Keying demodulator, low noise amplifier
Hocaoğlu et al. (2019)	Low-cost video and audio streaming device	The video is transmitted from the transmitter computer and uploaded in to the HDMI-AV converter. It is converted in to composite video baseband signal as well as stereo audio signals. The signals are subsequently transferred to the modulator and emitted out via the LEDs. Signal falls on to the photodiode at the receiver end and is converted in to an electrical impulse which is interpreted by the receiver circuits. The pulse is then sent to the AV-USB converter streamed on the receiver computer.	System uses cheaper sender and recipient circuitry compared to current models and therefore has the capacity for volume manufacturing	transmitter computer, HDMI-AV converter, LED light bulbs, modulator, photodiodes, AV-USB converter, receiver computer
Zachár et al. (2017)	Beaconing network for interior location application	An LED driver modulates the light discharged by each LED and each LED transmits a specific beacon ID. A camera is used in the detector and the picture sequence is used to identify pixels corresponding to the beacon IDs. Pixels sensed are used to locate image blobs corresponding to each beacon. The localisation method then determines the unknown position using the detection picture.	determining unknown position using localisation method	beacon detection segment, wide angle camera, LED bulbs, photodetectors
Dembla et al. (2018)	Li-Fi network grid system	The system composes of the grid server software and the grid client software with Li-Fi based interaction connections. The grid client software is activated on each client PC. The grid server program comprising of applications for event management and resource management is activated on the server computer. The server monitors different specifications such as storage capacity and computing power linked to the collective resources and activities on the network.	Monitoring specifications such as storage capacity and computing power linked to the collective activities on the network. It uses cheaper and faster speed connectivity resulting in simple implementation and enhanced functionality.	grid server software, grid client software, MySQL database

Optical fibers connecting the Li-Fi AP to the indoor gateway ensure backbone connectivity. An eNode B macro-cell base station links the indoor gateway to the mobile network. A set of Li-Fi activated devices are linked to the access points via VLC technology. It is assumed that each 5G device has an LED to interact with the respective Li-Fi AP. The LED is a straightforward, energy-efficient semiconductor device with many benefits such as environmentally friendly manufacturing, flexibility in design and better spectral efficiency (Abdallah and Boudriga, 2016).

It is also presumed that LED-to-LED communication is a form of Line of Sight (LoS) between the two communicating entities. The Li-Fi AP is installed in the home or office lighting infrastructure. We assume that at any time each VLC-based 5G unit is connected to one Li-Fi AP only. The Li-Fi AP is designed for indoor lighting and communication. Each attocell regulates and manages various communication equipment based on LEDs that are within their range. The Li-Fi AP should therefore be fitted with a significant quantity of resources, including processing energy and storage capacity (Dembla et al., 2018).

Hybrid Li-Fi/RF system model

In Purwita et al. (2018) the hybrid Li-Fi/Wi-Fi system is being investigated. This network provides indoor communication services (Purwita et al., 2018) with L Li-Fi APs, each fitted with N_L LEDs and a single Wi-Fi AP. This deployment evenly distributes a number of users fitted with a reconfigurable photodetector. For data transmission producing Co-Channel Interference (CCI) generation, each Li-Fi AP utilizes the same modulation bandwidth (Miras et al., 2018). The whole indoor area is covered by the RF scheme on the other hand. Each user is therefore linked to either a Li-Fi AP or to the RF AP for downlink wireless communication (Abdallah and Boudriga, 2016), assuming this architecture.

The Li-Fi / Wi-Fi hybrid network comprises of two-way communication transceivers for both Li-Fi and Wi-Fi connections and a Central Unit (CU) integrating these two distinct networks. For both Wi-Fi and Li-Fi signals, all users in the hybrid network are fitted with an RF antenna and a Photodiode (Haas et al., 2016). The CU frequently tracks the entire network in a short time and receives feedback from users on Li-Fi and Wi-Fi connections. Subsequently, it gives each user an appropriate AP and determines the communication for users linked to each AP (Ma et al., 2019).

In terms of capability, robustness, safety and reliability, the hybrid system provides significant advantages that are important metrics in a massively increasing internet in terms of amount of connected devices and transmitted information volumes. One of the sources of demand for this development is the Internet-of-Things (Purwita et al.,

2018). Table 2 summarizes Li-Fi network deployments showing the backbone connectivity and the uplink connection.

From the deployment architectures, we can see that Wi-Fi/Li-Fi hybrid architectures have been carried out and explored. Li-Fi technology has been used at the end points of the networks. Test networks can be setup and performance tests carried out on various network architectures. The test results based on packet loss, throughput and end-to-end delay obtained using iperf and ping test tools can be used to compare different setup performances and the outcome be used to determine the best setup and to develop deployment guidelines for application in areas such as hospitals, clinics and banks.

CHALLENGES FOR LI-FI BASED COMMUNICATION SYSTEM

Although the communication scheme based on Li-Fi provides many benefits, it faces distinct types of difficulties. These difficulties restrict its performance and may reduce the network's general effectiveness. Li-Fi does not operate under direct sunlight and other light sources, the required results may vary if these light sources block the route of the LED lamp's light ray (Do and Yoo, 2015). Line of sight connection provides high data rates because of the alignment of the transmitter and receiver field of view and the maximization of channel response. Nevertheless, practical situations can change the receiver field of view and shift it from one location to another thus causing loss of alignment with that of the transmitter.

This change in versatility and orientation substantially reduces the overall capacity of the network. In addition, light cannot pass through bricks or walls and other opaque materials, so Li-Fi can only be used in a single room. If one wants to relocate the receiver to a different place, they need to make sure that there is an LED bulb to connect to the receiver. It is therefore difficult to propose a Li-Fi model that can be used for large-scale communication (Chatterjee et al., 2015). It is vital that the LED driving circuit is linked to the web for Li-Fi based broadband network. The cost of using Li-Fi for internet and linking to wireless connections contributes to the slow data rate (Wang et al., 2014). Another disadvantage is that Li-Fi only functions with LED lights switched on. In other words, information cannot be relayed with the lights off, but it can when they are dimmed. This is a challenge as well as a concern for the energy bill and usage. Li-Fi only operates on gadgets that have a Li-Fi receptor (tablets, smartphones) (Aftab, 2016). Finally if the light source fails, we lose access to the web since Li-Fi communication depends on the light source for internet access (Chatterjee et al., 2015; Sathiyanarayanan et al., 2018).

Table 2. Li-Fi network architectures and backbone and end user connection.

Paper	Architecture	Backbone connectivity	Down link connection	Uplink connection
Miras et al. (2018)	Point to multi point Li-Fi Integrated system	Ethernet	Li-Fi	USB powered embedded dongle
Abdallah and Boudriga (2016)	Li-Fi indoor access network model	Optical fibers	Li-FI	Devices fitted with LED to interact with Li-Fi AP
Purwita et al. (2018)	Hybrid Li-Fi/RF Network	Wi-Fi AP	Li-Fi/ Wi-Fi	RF Antenna, Photodiode

FUTURE RESEARCH DIRECTIONS

Studies revealed that Li-Fi network has significant security problems (Classen et al., 2015). An intruder present inside or outside a room can use light signals acquired from the gap between the ground and door, cracks inside the ground or partly protected windows to eavesdrop. This threat shows that more study is needed to understand and address the Li-Fi network's safety and privacy concerns. In addition, light from any other energy source such as sunlight or an electric light source can interfere with a Li-Fi system by interrupting the LoS channel between transmitter and receiver. The interruption in the transmission route impacts data communication, so innovative techniques are needed to discover alternatives to this situation for indoor communication. No guidelines have been put in place so far regarding how efficient Li-Fi networks can be built to suit various applications. Li-Fi network integration with the cellular network and the optical fiber network has also not been investigated. Therefore these are also open areas for research. Lastly, the effect of shadowing and field of view misalignment are also reasons for blocking the LoS channel resulting in variations in received signals. Therefore, it is necessary to comprehend these impacts and to design methods that can manage the situations in order to provide desirable information rates all the time.

REFERENCES

Abdallah W, **Boudriga** N (**2016**). Enabling 5G wireless access using Li-Fi technology: An OFDM based approach. Int. Conf. Transparent Opt. Networks, vol. 2016-Augus, pp. 1–6.

Aftab F (**2016**). Potentials and challenges of light fidelity based indoor communication system. Int J New Comput. Archit Appl, 6, no. 3, pp. 91–102.

Cailean AM, Dimian M, Done A (**2018**). Enhanced design of visible light communication sensor for automotive applications: Experimental demonstration of a 130 meters link. 2018 Glob. LIFI Congr. GLC 2018, vol. 2018-Jan, no. 671, pp. 1–4.

Chatterjee S, Agarwal S, Nath A (**2015**). Scope and challenges in light fidelity (LiFi) technology in wireless data communication. Int J Innov Res Adv Eng, 6(2): 2349–2163.

Classen J, Darmstadt TU, Chen J, Steinmetzer D, Hollick M (**2015**). The Spy Next Door : Eavesdropping on High Throughput Visible Light Communications. Proceedings of the 2nd International Workshop on Visible Light Communications Systems. pp. 9–14

Dembla V, Chaudhari R, Joglekar B, Chhabra S (**2018**). Implementation of Grid System over Li-Fi Network. Proc. - 2018 4th Int. Conf. Comput. Commun. Control Autom. ICCUBEA, pp. 1–5.

Do TH, **Yoo** M (**2015**). Potentialities and challenges of VLC based outdoor positioning. Int. Conf. Inf. Netw., vol. 2015-Jan, pp. 474–477.

Ezhilazhagan C, Adithya R, Burhanuddin YL, Charles F (**2017**). Automatic product detection and smart billing for shopping using Li-Fi. 2016 IEEE Int. Conf. Recent Trends Electron. Inf. Commun. Technol. RTEICT 2016 - Proc., pp. 1723–1726.

Fang P, Bao Y, Shen J, Chen J (**2016**). A visible light communication based infra-to-vehicle intelligent transport demo system. 2015 Int. Conf. Connect. Veh. Expo, ICCVE 2015 - Proc., pp. 140–141.

Gavrincea CG, Baranda J, Henarejos P (**2014**). Rapid prototyping of standard-compliant visible light communications system. IEEE Commun Mag, 52(7): 80–87.

Haas H (**2016**). LiFi: Conceptions, misconceptions and opportunities. 2016 IEEE Photonics Conf. IPC, 1: 680–681.

Haas H, Yin L, Wang Y, Chen C (**2016**). "What is Li-Fi?" J Light Technol, 34(6): 1533–1544.

Hocaoğlu K, Adar A, Arıkök YA, Rodoplu V (**2019**). Design of a Low-Cost Visible Light Communication (VLC) System for Music and Video Streaming. 2019 Innovations in Intelligent Systems and Applications Conference (ASYU).

I. Standard and **I. C. Society** (**2011**). IEEE Standard for Local and metropolitan area networks — Part 15. 7 : Short-Range Wireless Optical Communication Using Visible Light. IEEE Computer Society. September. 2011.

Karthika R, **Balakrishnan** S (**2015**). Wireless communication using Li-Fi technology. Int J Elect Commun Eng, 2(3): 6-14.

Kulkarni S, Darekar A, Joshi P (**2016**). A survey on Li-Fi technology. Proc. 2016 IEEE Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2016, pp. 1624–1625.

Li-Fi (Light Fidelity)-The future technology In Wireless communication. [Online]. Available: **https://seminarsprojects.net/Thread-li-fi-light-fidelity-the-future-technology-in-wireless-communication**. [Accessed: 14-Sep-2018].

Lu HH, Li CY, Chen HW (**2017**). A 56 Gb/s PAM4 VCSEL-based Li-Fi transmission with two-stage injection-locked technique. IEEE Photonics J, 9(1): 1–8.

Ma W, Zhang L, Wu Z (**2019**). Location Information-Aided Load Balancing Design for Hybrid LiFi and WiFi Networks. 2019 Int. Conf. Comput. Netw. Commun. ICNC 2019, pp. 413–417.

Mamidkar S, **Samantray** R (**2018**). A survey on Li-Fi technology and its applications. Int J Sci Res, 7(7): 1388–1392.

Miras D, Maret L, Maman M, Laugeois M, Popon X, Ktenas D (**2018**). A high data rate LiFi integrated system with inter-cell interference management. IEEE Wirel. Commun. Netw. Conf. WCNC, vol. 2018-April, pp. 1–6.

Palanivel N, **Chen** T (**2018**). Wiring harness reduction in automotive using Li-Fi technology. Proc. 2017 Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2017, vol. 2018-Jan, pp. 1778–1783.

Prakash R, **Agarwal** P (**2014**). The new era of transmission and communication technology: Li-Fi (light fidelity) LED & TED based approach. Int J Adv Res Comput Eng Technol, 3(2): 285-290.

Pravin M, **Sundararajan** TVP (**2018**). VLC Based Indoor Blind Navigation System. 2018 9th Int. Conf. Comput. Commun. Netw. Technol. ICCCNT 2018, pp. 1–6.

Purwita AA, Soltani MD, Safari M, Haas H (**2018**). Impact of terminal orientation on performance in LiFi systems. IEEE Wirel. Commun.

Netw. Conf. WCNC, vol. -April, no. 1, pp. 1–6, 2018.

Sarkar A, Agarwal S, Nath A (**2015**). Li-Fi technology: Data transmission through visible light. Int J Adv Res, 3(6):1-10.

Sathiyanarayanan M, Govindraj V, Jahagirdar N (**2018**). Challenges and opportunities of integrating Internet of Things (IoT) and Light Fidelity (LiFi). Proc. 2017 3rd Int. Conf. Appl. Theor. Comput. Commun. Technol. iCATccT 2017, pp. 137–142.

Shah V, Chaudhary S, Jain B (**2017**). Architecture based on Li-Fi to enhance the working environment. Int J Adv Res Comput Commun Eng ISO, 6(2): 226–229.

Singh D, Sood A, Thakur G, Arora N, Kumar A (**2017**). Design and implementation of wireless communication system for toll collection using LIFI. 4th IEEE Int. Conf. Signal Process. Comput. Control. ISPCC 2017, vol. 2017-Janua, pp. 510–515.

Sudha S, Indumathy D, Lavanya A, Nishanthi M, Sheeba DM, Anand V (**2016**). Patient monitoring in the hospital management using Li-Fi. Proc. - 2016 IEEE Int. Conf. Technol. Innov. ICT Agric. Rural Dev. TIAR 2016, no. Tiar, pp. 93–96.

Wang N, Liu C, Lu Y, Shen J (**2017**). A Visible Light Communication (VLC) based Intelligent Transportation System for Lorry Fleet. 16th International Conference on Optical Communications and Networks (ICOCN) pp. 16–18.

Wang Q, Zhang X, Boyer KL (**2014**). Occupancy distribution estimation for smart light delivery with perturbation-modulated light sensing. J Solid State Light, 1(1): 17.

Wang Y, Videv S, Haas H (**2014**). Dynamic Load Balancing with Handover in Hybrid Li-Fi and Wi-Fi Networks. 2014 IEEE 25th Annu. Int. Symp. Pers. Indoor, Mob. Radio Commun., pp. 575–579.

Zachár G, Vakulya G, Simon G (**2017**). Design of a VLC-based beaconing infrastructure for indoor localization applications. I2MTC 2017 - 2017 IEEE Int. Instrum. Meas. Technol. Conf. Proc., pp. 1–6.

Zhu H, Zhang M, Wang C, Guo X, Zhang Y (**2015**). Design of a visible light Internet access system. Int. Conf. Ubiquitous Futur. Networks, ICUFN, vol. 2015-August, pp. 49–52.