DEVELOPMENT OF SECURE IOT WIRELESS COMMUNICATION SIGNAL USING VISIBLE LIGHT SOURCE FOR SMART HOME

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Abstract: To light up the world of technology, where wireless communication has bloomed to a great extend which requires a lot of data to be transmitted and received every fraction of the second a new era is coming. Electromagnetic waves such as radio waves are the main way to transmit wireless data, but certain limitations are there because radio waves can only support less bandwidth because of compact spectrum availability and intrusions. Visible Light Communication (VLC) has come to take way those issues. The new technology Li-Fi which stands for Light-Fidelity is a new kind of wireless communication system which uses light waves as a medium instead of radio frequency electromagnetic waves. This project presents an eco-friendly data communication system through visible light which consists of LEDs that transmit data to the receiver. According to the received signal, the information of present location at light source and further diversions is displayed on the LCD and speaker installed at the receiver. Thus, this technology provides better way rather than radio waves which could be an alternative choice for smart home projects in future.

Keywords: Visible Light Communication, Blynk Apps, Internet of Things, Li-Fi, VLC, LED, Smart home.

I. INTRODUCTION

Li-Fi, or "Light Fidelity", refers to wireless communication systems using light from light-emitting diodes as a medium instead of traditional radio frequencies, as in technology using the trademark Wireless Fidelity (Wi-Fi). Li-Fi is expected to be ten times cheaper than Wi-Fi.[1] Li-Fi has the advantage of being able to be used in electromagnetic sensitive areas such as in aircraft and nuclear power plants without causing interference.[2] The light waves cannot penetrate walls which makes a much shorter range, though more secure from hacking, relative to Wi-Fi.

More amounts of data can be sent through light because light waves are having a bandwidth 10,000 times more than radio-waves.[3] Using visible light for communication also reduces the risk of being exposed to radio waves. This Visible Light Communication (VLC) protocol, used for communication can be applicable in places where the radio waves are restricted like, secured military premises, airplanes, in some research area premises, and hospitals.

The general term Visible Light Communication (VLC) includes any use of the visible light portion of the electromagnetic spectrum to transmit information. The term Li-Fi was coined by Harald Haas from the University of Edinburgh in the UK.[4] The D-Light project at Edinburgh's Institute for Digital Communications was funded from January 2010 to January 2012.Haas promoted this technology in his 2011 TED Global talk and helped start a company to market it. Pure VLC is an original equipment manufacturer (OEM) firm set up to commercialize Li-Fi products for integration with existing LED-lighting systems.

In October 2011, companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. Several companies offer unidirectional VLC products.[5]

VLC technology was exhibited in 2012 using Li-Fi. By August 2013, data rates of over 1.6 Gbps were demonstrated over a single-color LED.[6] In September 2013, a press release said that Li-Fi, or VLC systems in general, do not require line-of-sight conditions. In October 2013, it was reported Chinese manufacturers were working on Li-Fi development kits.

VLC communication is modeled after communication protocols established by the IEEE 802 workgroup. This standard defines the physical layer (PHY) and media access control (MAC) layer. The standard can deliver enough data rates to transmit audio, video, and multimedia services. It takes count of the optical transmission mobility, its compatibility with artificial lighting present in infrastructures, the defiance which may be caused by interference generated by the ambient lighting. The MAC layer allows to use the link with the other layers like the TCP/IP protocol.

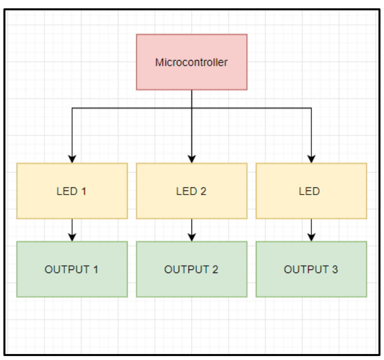
II. METHODOLOGY

2.1 Introduction

The experiments are conducted to identify a suitable Li-Fi transceiver pair, in the context of reliability and maximum communication distance. The integration of Li-Fi communication on the modules was performed with two different prototypes. This section also discusses the overview design choices, requirements, software architecture and implementation of the Li-Fi protocol such as:

- Design and construct circuit of Visible Light Communication by display any data on LCD, implementing variable light transmitter source and variable function of independent light source.
- Program the code that will be powered by the controller and integration of IOT based elements.
- Assembly the circuit based on working prototype tested and troubleshoot if there is any problem occurred.

A. Transmitter



. Figure 2.1:General Block Diagram of transmitter VLC system.

Depending upon the information to be transferred, data from the PC such as text message or programmed code is all transferred to the Arduino via direct connection from Universal Serial Bus (USB). A testing dashboard of input text message via MATLAB will be created to testing out the text output by using simulation method. The block diagram displays the data is transfer by using Single Input Single Output (SISO) which one LED will input single data with single output outcome.

B. Receiver

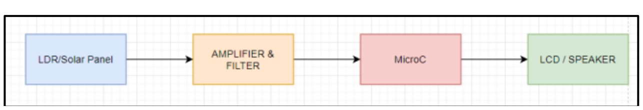


Figure 2.2: General Block Diagram of transmitter VLC system.

The information transmitted from the Li-Fi transmitter is received by the Li-Fi receiver based on Figure 2.2 and is amplified and sent to the Arduino. Then depending upon the information, the processed data is sent to the corresponding output. Then, LCD Display will display the text data or speaker that will produce sound to indicate the working output of this project.

2.2 Flowchart

The design implemented in this project is described below,

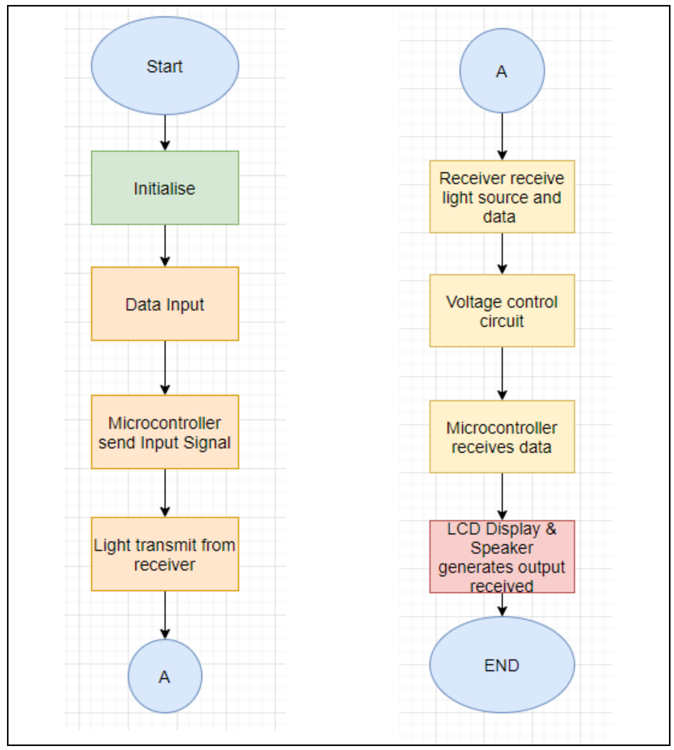


Figure 2.3: General Flowchart of Visible Light Communication.

2.3 Hardware Design of VLC Transceiver

The hardware design of VLC transceiver can be designed in two different variations. The Arduino-Mega 2560 is used as the controller, and blue color LED is used as transmitter and receiver. A 270 Ω resistor is used at the transmitter side, and 2 MΩ resistors are used at the receiver end. The LED based VLC transceiver, shown in Figure 2.4. The LDR based VLC transceiver is shown in Figure 2.5. LED as transmitter and LDR as the receiver. 270 Ω resistors are used at the transmitter and receiver end. The transmitter is connected to GPIO digital pin D4 and receiver is connected to GPIO analog pin A0 of Arduino-Mega 2560 controller.

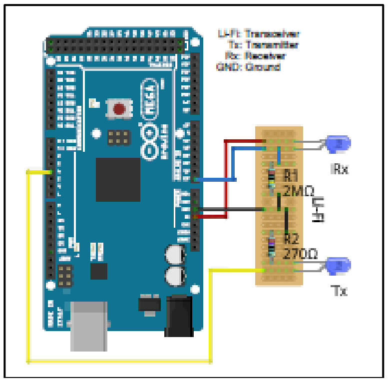


Figure 2.4: LED based VLC transceiver.

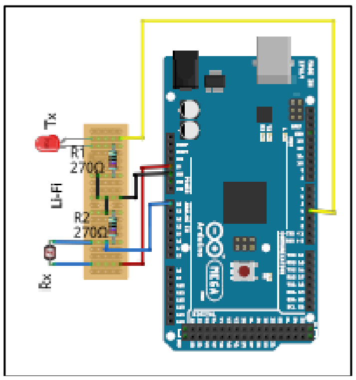


Figure 2.5: LDR based VLC transceiver.

In the smart home-based model, the VLC transceiver is attached to the model as shown in Figure 3.1. The VLC transceiver is achieved using programmed transceivers based on Manchester transmission algorithm. The Arduino controller is capable of handling the transceiver interfaces. The receivers are connected to the analog GPIO pins from A0 to A3. The transmitters are connected to the digital GPIO pins from D4 to D7.

III. RESULTS AND DISCUSSION

3.1 Testing Parameters

A. Maximum Communication Distance

The objectives of this experiment are to find the maximum communication distance and to identify a suitable transceiver pair. In the first iteration, the communication distance is measured with TICK size of 3 ms. A series of iterations are performed to find the maximum communication distance. In the next instance, the TICK size is changed to 4 ms and continued with the same procedure to find the communication distance. The maximum communication is verified with different color LEDs as transceivers.

Colour of LED	Communication Distance in (cm) with different TICK size (*Based on single LED Transmitting on each test.)							
	3ms TICK				4ms TICK			
Testing Count	Test 1	Test 2	Test 3	Average	Test 1	Test 2	Test 3	Average
RED	5.8 cm	6.1 cm	6cm	6cm	17.2 cm	17 cm	17 cm	17 cm
BLUE	8.1 cm	8.1 cm	7.9 cm	8 cm	29.0 cm	29.1 cm	30 cm	29 cm
YELLOW	2.7 cm	3.0 cm	2.9 cm	2.9 cm	13 cm	13.1 cm	13 cm	13 cm
GREEN	4.2 cm	4.4 cm	4.4 cm	4.3 cm	24 cm	23 cm	23 cm	23 cm
WHITE	30 cm	30 cm	29 cm	30 cm	65 cm	68 cm	68 cm	66.5 cm

Table 3.1: Testing Matrix for LED Communication Distance of Visible Light Communication.

B. Reliability of Visible Light Communication

The aim of this testing method is to find the reliability of Visible Light Communication between two nodes, based on different communication distances, payloads and TICK sizes. Initially, both transceivers are placed at 5 cm communication distance with TICK size of 3 ms. In the next instance, the TICK size is changed to 4 ms and the communication distance is set to 5 cm. A series of iterations performed to compute the reliability of Visible Light Communication with different parameters.

Payload	Difference communication Distance in (cm) with Reliability of transmitter and receiver (WHITE LED)							
	3ms TICK				4ms TICK			
Distance	5cm	10 cm	15 cm	20cm	5 cm	10 cm	15 cm	20cm
1B	99%	97%	96%	96%	99%	98%	97%	95%
2B	99%	98%	96%	96%	97%	96%	96%	95%
3B	98%	96%	95%	94%	97%	96%	95%	95%
4B	97%	96%	95%	93%	97%	96%	95%	94%
5B	97%	95%	93%	91%	96%	95%	94%	93%

Table 3.2: Testing Matrix for LED Communication Reliability of Visible Light Communication.

C. IOT Blynk Distance & Reliability Communications

The main objectives of this testing parameters are to test the Visible Light Communication on LED status monitoring on data receive through LED to LDR for creating a scenery of smart home functionality. The IOT Dashboard will features some of functionality of displaying time, push button for checking circuit functionality of LED, display brightness of LED and notification of microcontroller.

White LED	Difference communication Distance in (cm) with Reliability of transmitter and receiver							
	3ms TICK				4ms TICK			
Distance	100cm	200cm	300 cm	400 cm	100cm	200 cm	300cm	400 cm
1B	99%	98%	95%	94%	99%	98%	97%	95%
2B	99%	97%	95%	93%	98%	95%	95%	94%
3B	96%	94%	93%	92%	96%	95%	94%	94%
4B	95%	94%	92%	92%	93%	92%	92%	91%
5B	94%	93%	92%	91%	91%	90%	90%	89%

Table 3.3: Testing Matrix for Distance & Reliability Communication Distance with IOT Blynk integration

3.2 Prototype scale design

A. Receiver node

The receiver node consists of a controller, Light Diode Resistance, LED and LCD Display for display the output source of the Visible Light Communication. The receiver node will be collecting data under the transmitter node and process the information data to the LCD Display. The workaround of the decode parts of the programing is configured with Manchester Encoding. The receiver will be integrated with IoT integration for monitoring functionality.

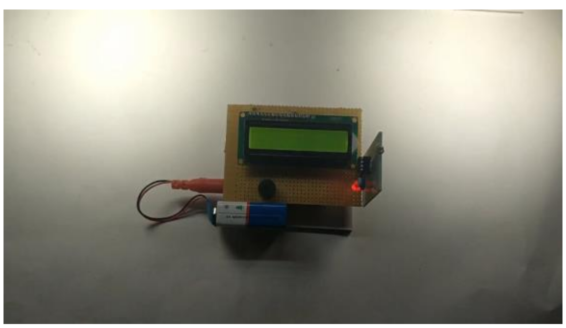


Figure 3.1: Prototype of receiver node at initial mode

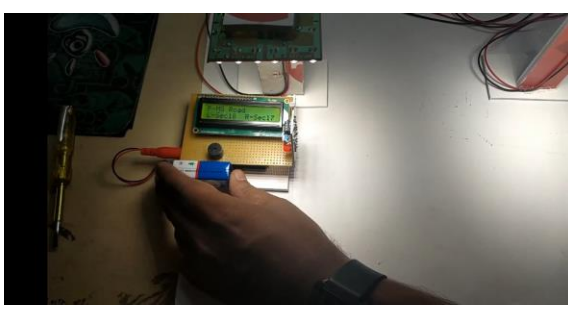


Figure 3.2: Receiver under LED transmitter shows data on LCD Display.

B. *Transmitter node*

The transmitter node was combined in another microcontroller which consist of White LED as the medium for transfer of data, Arduino ATMega 328P as the core, battery, and some component holders. The LED transmitter node will be built on 3 different output which means there are three different transmitter that will tested on. The connection was shown in Figure 3.3 and Figure 3.4.

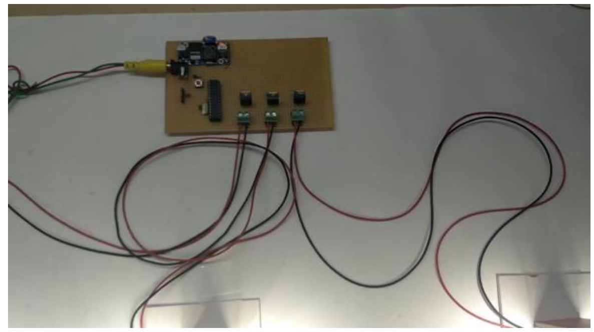


Figure 3.3: Circuit of transmitter node constructed on the breadboard.

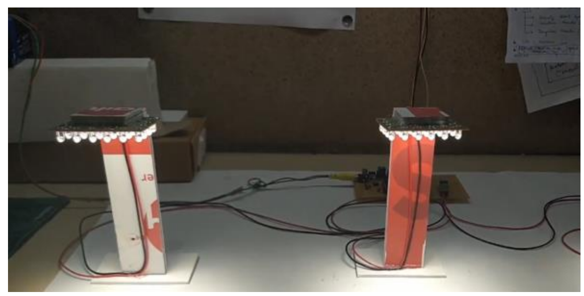


Figure 3.4: Transmitter LED pole lamp of Visible Light Communication.

C. *IoT Integration via Blynk Apps*

The transmission and reception of data through VLC is demonstrated in Figure 3.2. Transmission of data from input device takes place when the data is sending from the transmitter LED pole to receiver node of the Visible Light Communication as designed earlier. The transmitted and received information can be seen in Figure 3.5.

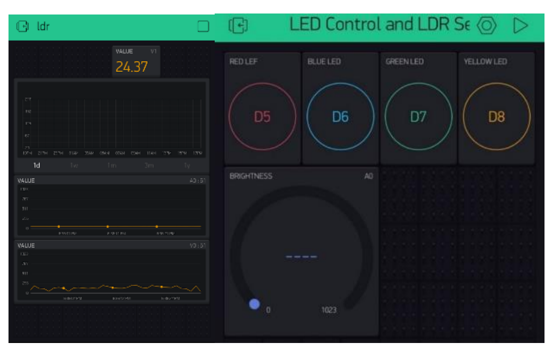


Figure 3.5: Blynk IOT Dashboard of LDR Status.

D. *Experiment Results*

NO	TEST DETAILS	METHOD	RESULT	STATUS
1	Checking prototype status	Power up prototype with battery and USB powered source	Prototype both transmitter and receiver initialize well & functioning	PASSED
2	LED data transmit	Placed receiver under LED (transmitter source)	Short word displayed on LCD Display	PASSED
3	IOT Integration	Connect microcontroller via Blynk to monitor LED status	LED status were shown on Blynk on the receiver node via LDR	PASSED
4	Blocking transmitter source	Add a obstacle nearby	Data not shown on LCD Display	PASSED
5	Different scene effect to transmitter and receiver	Place under normal lightings indoor	Data shown a bit delay since having ambient light source	Smaller scope will specify the uses of VLC in early stage
6	Battery duration for power supply	Placed with receiver for standalone prototype	Can withstand for long period as the transmitter node only use low power 5V, 1A max	PASSED
7	Testing other microcontroller as a part of the transmitter and receiver node	Adding support for NodeMCU ESP 8266	Not much significant details acquired, but powerful core will much having more transmission speed for the project	PASSED but can be improved
8	Flicker on LED Transmitter	Observe on LED Transmitter behaviour	Acceptable, a bit flicker since the data were transmitted to the receiver node	PASSED but can be improve

Table 3.4: Testing Visible Light Communications

3.3 Discussion

A. *Maximum Communication Distance*

From the graph shown in Figure 3.6, the communication distances of other LEDs show that the white LED as a transmitter and LDR as a receiver can be used for the best design of Visible Light Communication transceiver.

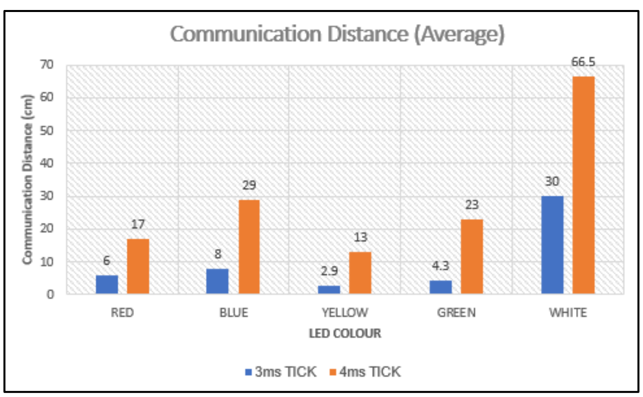


Figure 3.6: Bar chart for average LED Communication Distance of Visible Light Communication 3ms & 4ms.

B. *Reliability Communication of VLC*

The graph shown in Figure 3.7 explains the increase in distance with constant payload decreases the reliability. The reliability of 3 B payload with different communication distances is explained in the graph. The graph illustrates the influence of TICK size on reliability. If the communication distance is more,then 4 ms TICK size gives slightly better reliability.

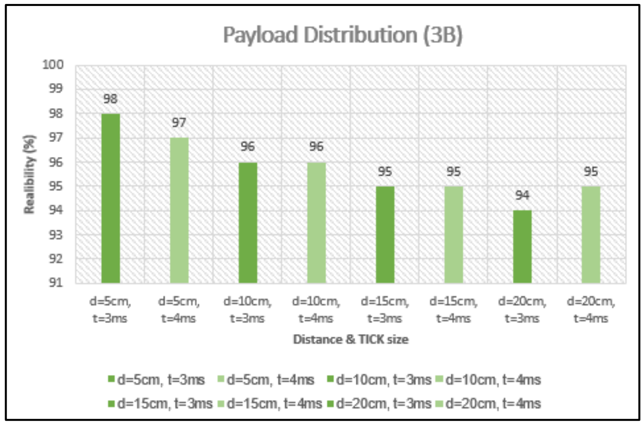


Figure 3.7: Reliability with different communication distance and constant payloads.

C. *Performance evaluation*

The performance of VLC protocol is evaluated based on the transmission time of frame. Initially, the transmission time is calculated with different parameters and information frame. The parameters of VLC protocol to compute the time required to transmit 1 B of payload with overhead are as follows:

- TICK(T) = 3 ms and 4 ms and 5 ms // number of milliseconds per Tick
- CLOCK_HALF(c) = 5 // number of ticks per half clock
- CLOCK(C) = (2 * CLOCK_HALF) //number of ticks per clock (1 bit of data)

The calculation of transmission time for 1 B payload is shown below. The calculation is repeated by using different TICK with same steps.

$$T = 3 \text{ ms} \tag{4.1}$$
$$c = 5 \times 3 \text{ ms} \tag{4.2}$$
$$=15 \text{ ms} \tag{4.3}$$
$$C = 2 \times c \tag{4.4}$$
$$=30 \text{ ms} \tag{4.5}$$
$$1 \text{ bit} = 30 \text{ ms} \tag{4.6}$$
$$\Rightarrow 1 \text{ B} = 8 \times 30 \text{ ms} \tag{4.7}$$
$$=240 \text{ ms} \tag{4.8}$$
$$8 \text{ B} = 8 \times 240 \text{ ms} \tag{4.9}$$
$$=1920 \text{ ms} \tag{4.10}$$

The graph shown in Figure 3.8 explains with smaller TICK size the transmission time is less compared higher TICK size for the same amount of data transmitted.

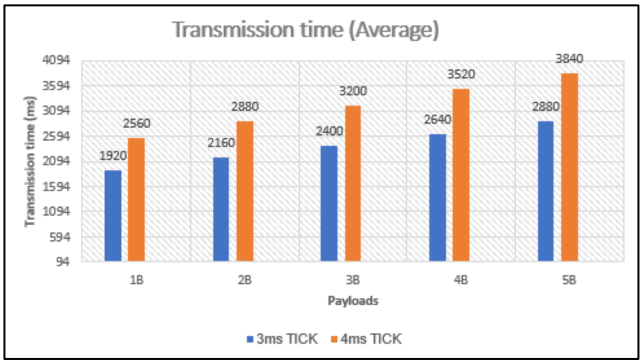


Figure 3.8: Transmission time with different TICK sizes.

IV. CONCLUSION

This paper presents a VLC prototype developed under various test which integrates the IoT functionality for smart home use. The VLC was implemented in Arduino software and loaded onto the Arduino board. A UI was developed using Blynk that allows the user to control and observe the communication between two entities. Working of the developed prototype was validated through different test cases. The validated results demonstrate successful implementation of VLC. In future, the developed prototype can be enhanced to be implemented in reality. More systems can be added to transfer data among themselves and effect of interference between the communicating devices can be studied.

V. REFERENCES

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