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Design and Implementation of Visible Light Communication System using low cost microcontroller module and LED as light source

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***Abstract*— Over the last few decades, the demands for wireless internet becomes increasing very rapidly which influences the birth of new technology in the wireless domain. Li-Fi is such a technology that transmits data through illumination by taking a LED light bulb that varies in intensity faster than the perception of the human eye. Data in the form of strings of 1s and 0s are placed at the input driver circuit of the LED bulb. The output of the LED intensity appears to be constant to the human eye as the intensity is modulated rapidly. This method of transmission of light in the wireless medium is known as Visible Light Communication (VLC). This technology can replace the today's' Wi-Fi router with a LED bulb that transmits data wirelessly in the form of light and will proceed toward a cleaner, greener, and safer future.**

***Index Terms*—Visible light communication, Pulse Width Modulation (PWM), LED as light source, Wireless Data Transmission.**

I. INTRODUCTION

The visible light communication (VLC) system uses much wider bandwidth (380 nm to 750 nm) [1] than radio waves and microwaves and also it transmits the data in the form of light through the wireless medium which further add the mobility feature in this communication system. Therefore the demand for this communication system is increasing day by day.

LED is more advantageous than the existing incandescent regarding long life expectancy, high tolerance to humidity, low power consumption, and minimal heat generation lighting. LED is used in full-color displays, traffic signals, and many other means of illumination. Therefore VLC system should be employed with LED to achieve better performance than the existing other light sources. The transmission using LED can be performed by using Intensity Modulation (IM), while the reception is done by using Direct Detection (DD) method. The intensity of LED can be varied by using several modulation techniques such as On-Off Keying (OOK) [2] for low data rate (10 Kbps), or Orthogonal Frequency Division Multiplexing (OFDM) [3] that can provide a data rate of up to 100 Mbps. OFDM has a drawback of high Peak to Average Power Ratio (PAPR). This will cause a dimming effect on LED which disrupts the lighting system. Also, there is a complex hardware implementation of OFDM which makes it very expensive. Thus, we need another modulation scheme for moderate data rate application such as textual communication via VLC.

In this paper, we proposed an alternative modulation scheme, known as pulse width modulation (PWM) using a microcontroller system that provides an efficient and accurate moderate speed data transfer for textual applications without disturbing the illumination system.

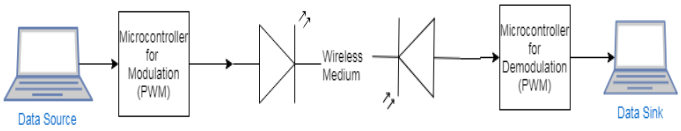

Fig. 1: Proposed Model of Visible Light Communication System

II. SYSTEM DESIGN

The components used to design the VLC system is listed below.

i. Arduino Uno R3: Arduino Uno is a microcontroller board based on the ATmega328P (with 16 MHz crystal clock) microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, an ICSP header and a reset button.

Fig. 2: Arduino Uno Board

ii. Arduino data port cable: An Arduino serial port cable is used to burn the programming instructions in the Arduino board from computer. Also it can be used for serial communication between Arduino board and computer.

Fig. 3: Arduino data port cable

iii. Light Emitting Diode: A light emitting diode is a two lead semiconductor light source. It is a p-n junction diode that emits light when activated. When a suitable current applied to the leads electrons are able to recombine with hole within the depletion region of the device that release energy in the form of photons. This effect is called electroluminescence, and the color of the light is determined by the energy band gap of the semiconductor.

Fig. 4: LED as light source

iv. Light Dependent Resister (LDR): An LDR is a resistive component whose resistance changes with the light intensity that falls upon it. This allow them to be used as a light sensing device or a photodetector.

Fig. 5: LDR as photodetector

Using the above components we have designed our VLC system which composed of a transmitter section and a receiver section. In the transmitter section, the data is inputted from the keyboard of the computer to the serial monitor of Arduino IDE. Here we have used Arduino IDE of version 1.8.3. From there the textual data is first converted to a stream of binary data and transmitted to the Arduino serial port via the USB to serial converter cable. Now according to the logic 0 or logic, 1 of the binary data stream the blinking rate of LED is varied. At the receiver, a photodetector (LDR) is there to capture the blinking rate of LED and generate the binary bit pattern accordingly. After the generation of the binary bit pattern, the proper algorithm is used to convert the textual data from the binary data stream which is displayed at the serial monitor of Arduino IDE at the computer of the receiving section. The complete circuit diagram of VLC system is shown below.

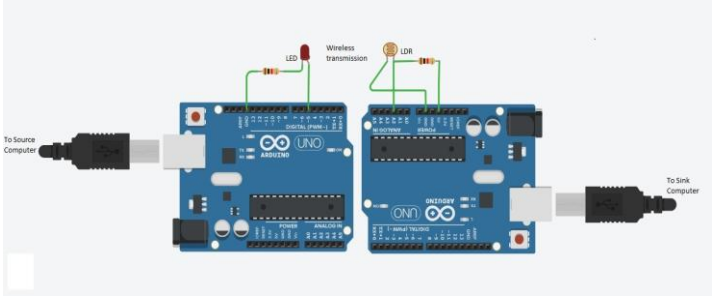

Fig. 6: Circuit diagram of complete VLC system

III. Working Principle

The principle of behind this communication system is that the textual, voice or video data is first converted into binary data using any one source coding algorithm. Here we used simple ASCII to binary conversion methodology. After that this raw data is converted into pulse waveform using Pulse Width Modulation technique and then fed into a single or an array of LEDs so that the duty cycle or ON and OFF time of LED/LEDs will vary according to the variation of pulse data width.

On the receiver side, a single or a group of photodiode or LDR (Light Dependent Resistor) is used to detect the rate of blinking of LEDs and generate an output voltage depending on the intensity of the LEDs. Here we have used CdS based LDR with a sensing delay of 100ms. The logic 1 and logic 0 can be distinguished based on the duration of the illumination of LED. The variation of the output voltage due to blinking of LEDs is used to generate the binary bit pattern. Since the photodetector has a sensing delay of 100 ms, therefore we have chosen header bit duration of 110 ms, logic 1 duration of 115 ms, logic 0 duration of 120 ms, and trailer bit duration of 125 ms for detection of the binary data stream. Finally, the proper decoding algorithm will convert the binary data into an ASCII equivalent textual data. So a reliable communication can be ensured using our proposed VLC system. The algorithms used to design the transmitter and receiver for VLC system is shown below.

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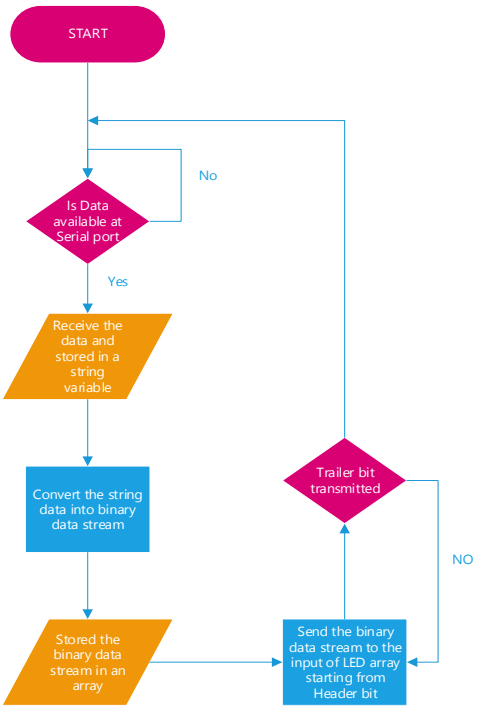

Fig. 7: Transmitter Algorithm

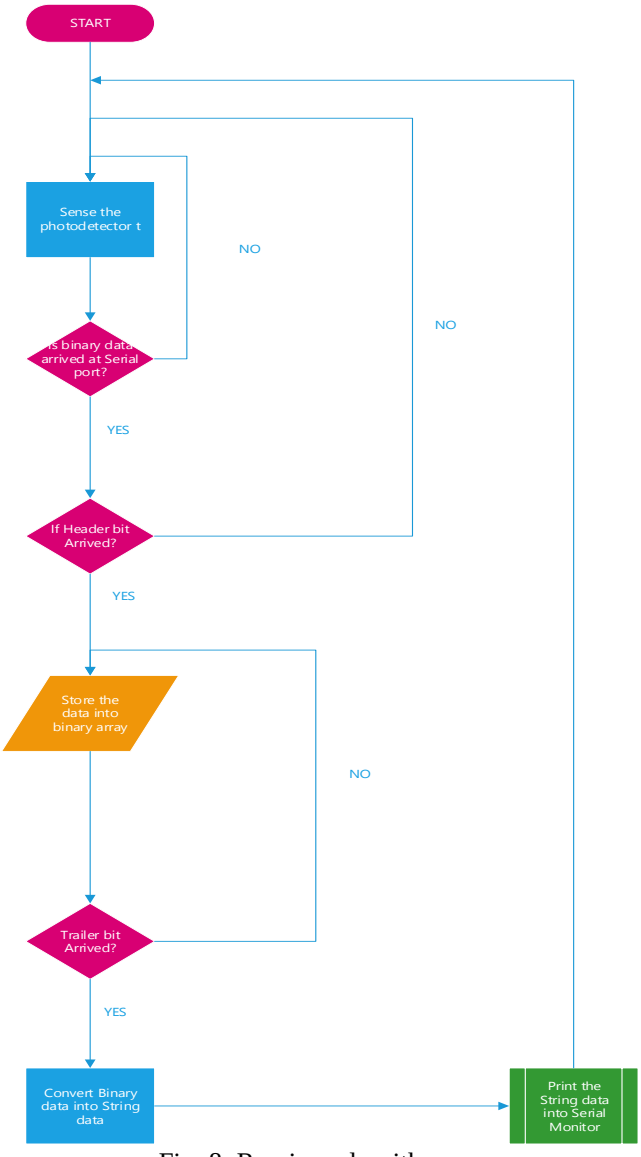

Fig. 8: Receiver algorithm

IV. Result & Discussion

The following figures shows the snapshot of the transmitter and receiver for VLC system where in the transmitter section the user wish to transmit a string of data will enter the string through serial monitor and the underlying algorithm which is mentioned in the preceding section is used to convert the data string to a stream of binary data. Finally this data stream is fed into the input of the LED source so that the blinking rate of LED will vary according to the arrival of logic 1 or logic 0 at the input the LED.

```
The entered string is:
Hello World

No of decimal values is:13
Decimal Converter:
Decimal value for character:H
72
Decimal value for character:e
101
Decimal value for character:l
108
Decimal value for character:l
108
Decimal value for character:o
111
Decimal value for character:
32
Decimal value for character:W
87
Decimal value for character:o
111
Decimal value for character:r
114
Decimal value for character:l
108
Decimal value for character:d
100
Decimal value for character:
13
Decimal value for character:

10
Raw binary data towards optical source is:
0100100001100101011011000110110001101111001000(
Header bit Transmitted
0 Transmitted
1 Transmitted
```

Fig. 9: Transmitter output snapshot

At the receiver side the binary data streams are detected by the photodetector are send to the microcontroller unit where proper decoding algorithm is used to reconstruct the original textual data which is finally displayed at the serial monitor of the Arduino IDE in the computer at receiver side.

```
Maximum character limit is 20
Data Not Available
Data Not Available
Data Not Available
Binary data
01001000011001010110110001101100011011
Decimal Equivalent is:
72
101
108
108
111
32
87
111
114
108
100
13
10
Received Text=
Hello World
```

Fig. 10: Receiver output snapshot

V. Study of Marketability

This product is manufactured by keeping in mind the trend in increase the speed of the data rate and channel bandwidth. As everybody in the world is highly connected in social networks, we think that our modern VLC system will help us to wipe the problems from our society.

In hospitals, defence, transportation it is very easy to install VLC system so that this system can replace the prevailing problems of Men and give us the high speed data.

VLC system is not only cost effective but it is also accurate. Apart from that low installation charge and less manpower can reduces the time consumption for installation and maintenance.

VI. Conclusion

VLC is one of the cost efficient methods of data transmission method that may lead the market in near future. Data transfer capable using LED light helps us to long life expectancy, high tolerance to humidity, low power consumption, and minimal heat generation lighting. Also use of PWM scheme of modulation can provides an efficient and accurate moderate speed of data transfer for textual applications without disturbing the illumination system.

VII. Future Scope of Work

Although the VLC system provides more bandwidth and mobility than the existing wireless communication systems but the problem with this free space optical communication is that the external noise of other visible light sources may lead to introduce interference in the communication system. Therefore the challenging aspect is to carefully design the filter at the detection end to ensure the reliable communication. Also, the maximum data rate of this VLC system is limited by the propagation delay in the wireless medium, sensing delay of the photodetector, and processing delay of the microcontroller unit. The propagation delay can be minimized by reducing the transmitter-receiver separation distance, & processing delay is minimized by the high-speed processor with clock speed in several GHz. To minimize the sensing delay a proper design of the photodetector is required which should overcome the delay between photon absorption and electron-hole pair generation. So, more research work should be carried out on the design of photodetector with small sensing delay.

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