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Efficient Data Transmission Using Visible Light

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Abstract- **Wireless communication using visible light is an exciting prospect which has started gaining a lot of attention recently. This is because this branch of communication has several advantages over using RF, such as the fact that the visible light spectrum is still unlicensed, which can solve the problem of present status of congested RF spectrum, secondly the infrastructure already exists, all that needs to be done is to replace the current light bulbs with intelligent and efficient bulbs capable of data transmission. A lot of research and development is being done in this hot field of wireless communication, but most of which is focused on increasing it throughput/data rate and very less has been concentrated on utilizing it for short range indoor applications such as using it as a Wireless Sensor Node.**

Keywords: **Wireless communication, RF spectrum, wireless sensor node.**

I.INTRODUCTION

VLC (Visible Light Communication) refers to transmission of information using visible light portion (380nm to 780nm) of the electromagnetic spectrum. LED (Light Emitting Diode) is used as a transmitter, air as the transmitting medium and an appropriate photodiode acts as the signal receiving component. In the last two decades, there has been a tremendous increase in the demand for wireless data communication. Wireless communication using radio frequency spectrum being the most popular till the present era has led to the congestion of this spectrum. Since Wi-Fi's accidental invention in 1992 by an Australian astronomer through an unsuccessful experiment to observe mini black holes Wi-Fi has revolutionized the digital communication. Wi-Fi presently contributes to 60% of the web traffic globally. However, Wi-Fi still has some problems like it is not entirely secure because these signals can travel through walls and be simply picked up by some other person, it uses radio waves that is restricted, expensive and there's a certain limitation. So how do we improve this technology and solve these problems? We've to use something thing that's low cost, safe, in abundance and sturdier for data transfer. The solution is light; light is ideal because it's a part of the electromagnetic spectrum just like radio waves however at a much higher frequency. The frequency range of light is ten thousand times bigger than radio waves i.e. 750 terahertz as compared to amaximum of 300 GHz for radio waves, which suggests that light is capable to transmit more pulses of data in much less time as compared to radio waves. The spectrum of light is 10,000 times bigger than the spectrum of Radio waves and this is still unutilized and can be used.

II.SYSTEM MODEL

For the analysis two approaches were used, one was to create a VLC system with OOK modulation and other was to create a VLC system with OOKmodulation and Manchester coding technique.

2.1. Design of Prototype 1 (On Off Keying Modulation)

This prototype was designed to show the communication between two Nodes, sending and receiving temperature data via visible light as a mode of communication.

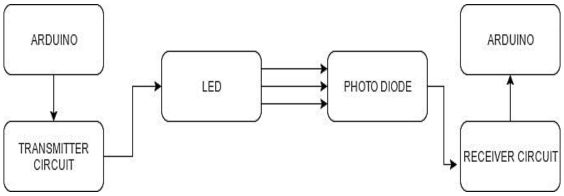

Fig. 1. Block Diagram of VLC

Figure 1showsthe block diagram of Prototype 1. The Arduino development board is connected with a PC via a USB which provides power and also a user interface for monitoring the data transmitted and received. The transmitter circuit contains a temperature sensor and a LED driving circuit connected to the ATmega328P microcontroller which is mounted on the Arduinoboard.The input message is converted into 8-bit binary number. This8-bit binary data is then transmitted serially via the LED. The LED provides the visible light as a carrier to the signal. The modulation scheme used here is on-off keying (OOK) i.e. modulating the intensity of light source and demodulating it at the receiver. This modulation scheme is implemented on software level. This means that the informationbits are encoded into the number of photons which are then transmitted and received by the receiver i.e. a photodiode in thiscase. Thephotodiode then receives the incoming photons and converts it into the 8-bit number which isthen displayed on the PC2 as the received data.

2.1.1. Transmitter

The transmitter is designed to transmit the message which is an 8-bit long numeric value. The transmitter module for this prototype includes a LED driving circuit which are connected to the Arduino development board. The message is converted into ASCII value and then converted into binary form by the microcontroller which then delivers it to the driver circuit for fast switching of LED. The data received from microcontroller is then modulated using OOK modulation.

The schematic for the transmitter can be seen in Figure 2 below

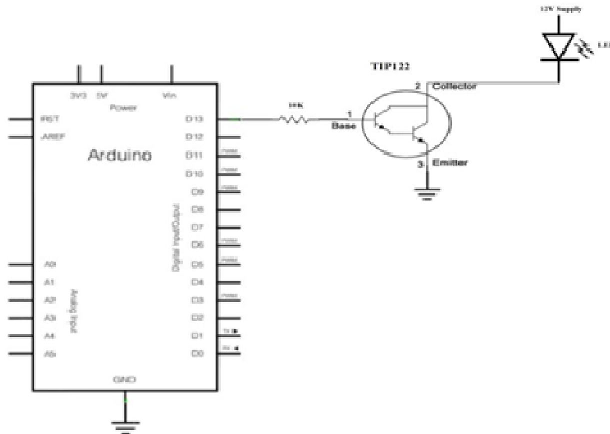

Fig. 2. Circuit Diagram of Transmitter

2.1.1.1 Algorithm for transmission

This section will explain about the working of the transmitter on software level, how the data is acquired, modulated and transmitted.

The message along with the transmitter ID which are 8-bit decimal value are then packaged into a 16-bit frame where the 8-bitID value acts as a preamble. The frame is then transmitted starting from the MSB to the LSB by the means of LED, which is turned ON for every binary '1' and turned OFF for every binary '0'. Here visible light acts as a carrier for the signal data bits. Figure 13 below shows the algorithm followed for this process.

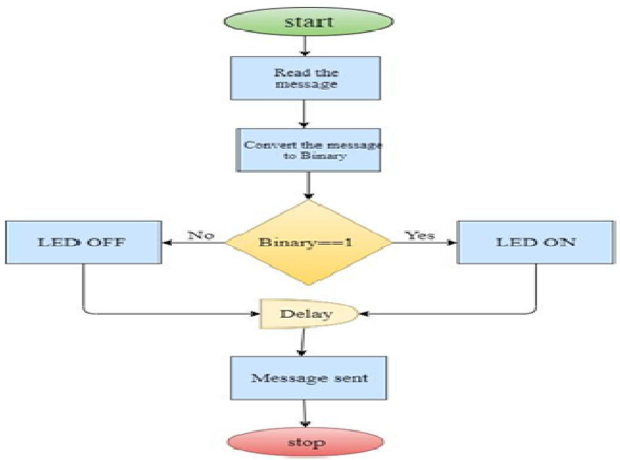

Fig. 3. Algorithm followed for Transmission

2.1.2 Receiver

The receiver module compromises of a photodiode, recalibrating the photodiode according to the ambient light and setting the threshold value for the photodiode, ATmega328P microcontroller mounted on Arduino board for analog to digital conversion (ADC) & demodulation and a PC for monitoring the result.

The schematic for the receiver can be seen in Figure 4. below.

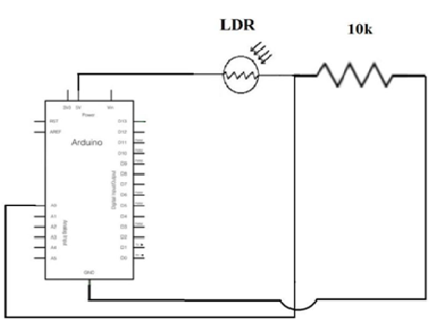

Fig. 4. Circuit Diagram of Receiver

The photodiode detects the incoming optical signal from the LED and converts it into electrical signal. Initially a threshold value is set by the photodiode according to the ambient light present. This threshold value determines whether the received binary signal is representing logic '1' or logic '0'. After that the analog to digital conversion is done by the microcontroller.

2.1.2.1 Algorithm for Receiver

This section will explain about the working of the receiver on software level, how the receiver is calibrated for compensation of ambient light, data is acquisition and demodulated.

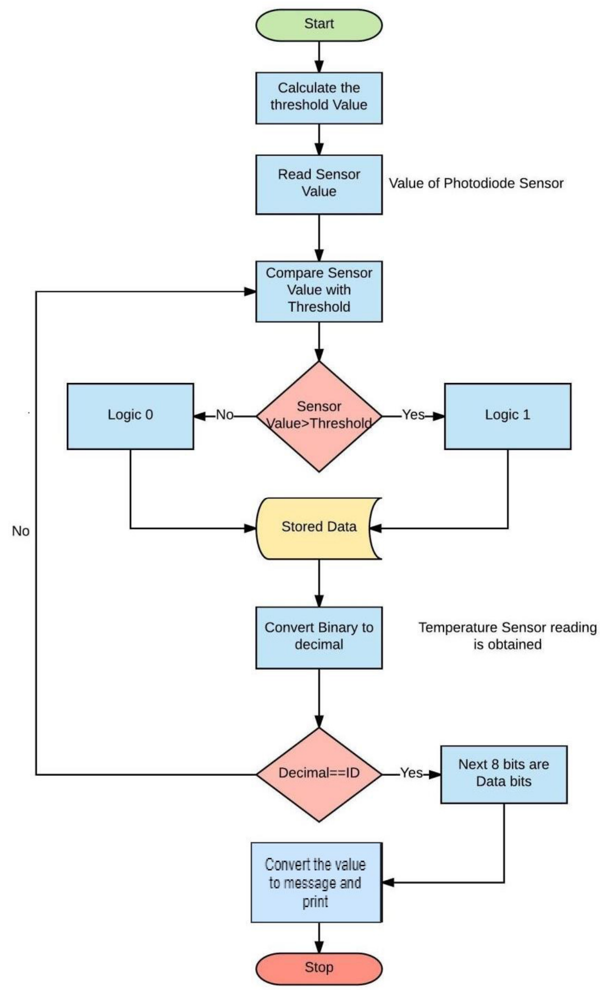

Fig. 5. Algorithm followed for Receiver

Figure 5. Shows the algorithm for the receiver module on turning ON the receiver, a threshold value for distinguishing between the logic '1' and logic '0' is calculated, by setting this threshold value the receiver is also calibrated according to the ambient light.

Since the data received is in binary form, it is converted into decimal value. The 8-bit information is read from MSB to LSB by comparing the sensor value with the threshold value. For making sure that the correct data being received is from the correct transmitter, an ID is sent by the transmitter which is first matched with the ID of the receiver. If the ID of both Transmitter and Receiver match, then only further reception of signal occurs which is the data bits.

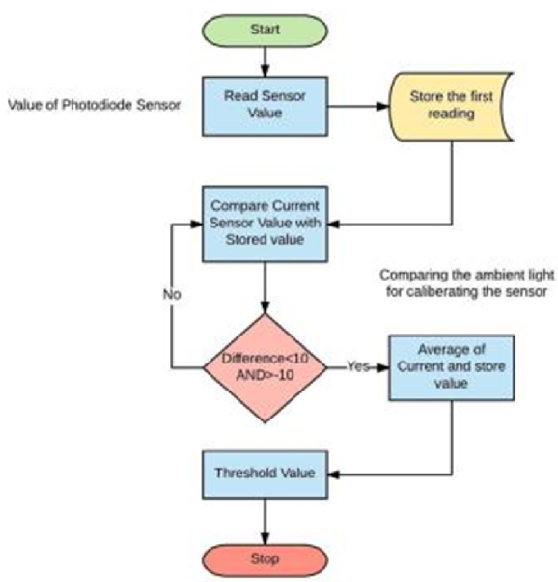

Fig. 6. Algorithm used for Calibrating the Receiver

The Figure 6 below explains the algorithm used for calibrating the receiver according to the ambient light and for calculating thethresholdvalue. For setting this threshold value the photodiode sensor takes one initial reading and stores it, then this initial reading is compared with several consequentreadings until the difference between the initial reading and concurrent readings is high enough to be in limit of -10 and 10. Then an average of the current value and the initial reading is taken which determines the threshold value. This threshold value helps the receiver for differentiating between Logic 1 and Logic 0.

2.2 Design of Prototype 2 (On Off Keying Modulation with Manchester Coding)

This section will explain about the implementation of the second prototype i.e. VLC system with Manchester coding. On hardware level this system is same as that of Prototype 1 but all the changesare implemented on software level which are explained in subsequent sections.

2.2.1 Manchester Encoding

Manchester encoding is a coding technique used in many communication systems inconjunction with OOK. This method encodes azero into the sequence 01and the one into the sequence10. This has an advantage in a VLC system like toavoidflickering. Even at high frequencies alongsequence of zeros followed by a long sequence of ones will be perceived as annoying flicker of the LED. Manchester encoding solves this by always sending an equal number of ones and zeroes i.e. each bit is sent as a transition from the low state to the high state being encoded as "1" and a transition from high state to the low state being a "0".

The disadvantage of Manchester encoding is that every logical bit is sent using two physical bits, and as a result the transfer speed is halved compared to OOK without Manchester encoding. How the bits are encoded is displayed in Figure 7 below.

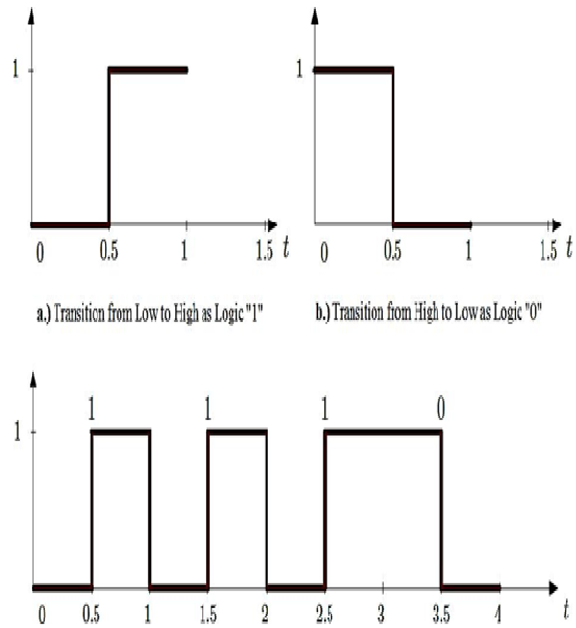

Fig. 7. Encoding of bits using Manchester coding

From the above figure, we can see that at each mid-point of a signal the state changes. It shows the representation of a binary sequence 1110 in Manchester encoding.

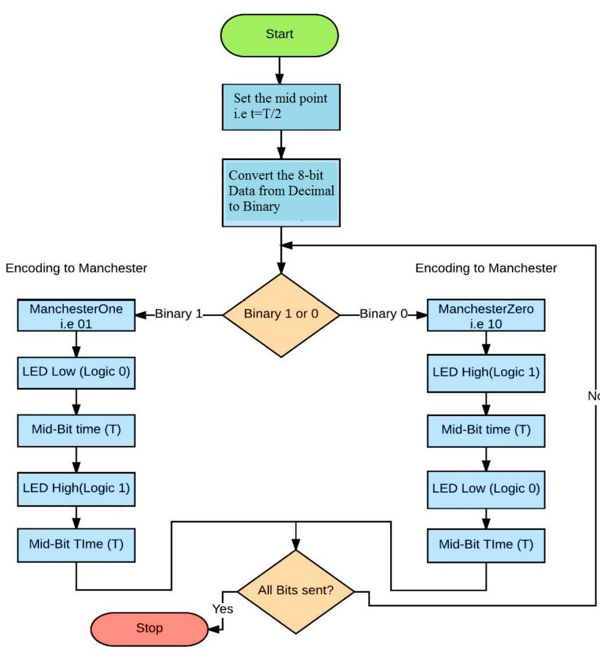

Fig. 8. Algorithm for Implementing Manchester Encoding

2.2.2 Manchester Decoding

Manchester decoding is the part where most of the problems arise and have to be done carefully. The most important and complex part in Manchester decoding is synchronization, i.e. making the receiver able to detect the transition point or the edge coming from the demodulation circuit. Atmel corporation has explained the process of Manchester encoding anddecoding very clearly in its documentation. Figure 9 Shows the algorithm for implementing Manchester Decoding on the microcontroller.

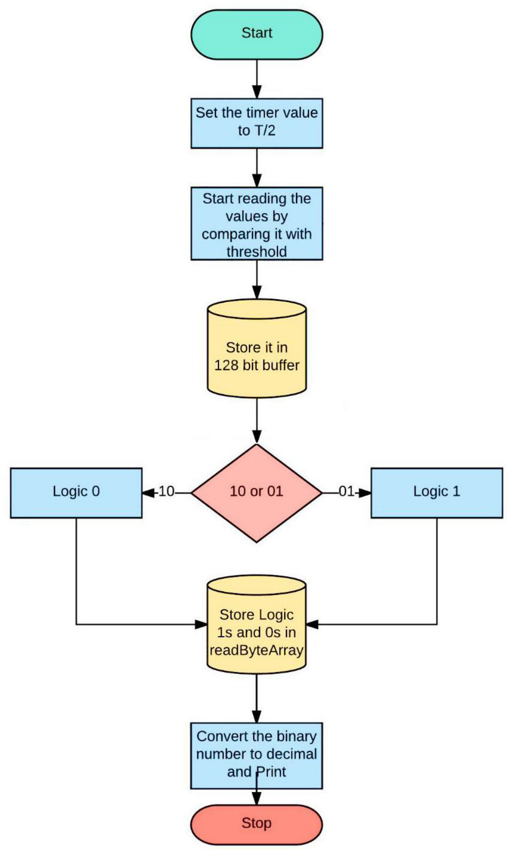

Fig.9.Algorithm for Implementing Manchester Decoding

III . RESULT

3.1 Two Nodes with and without Manchester coding

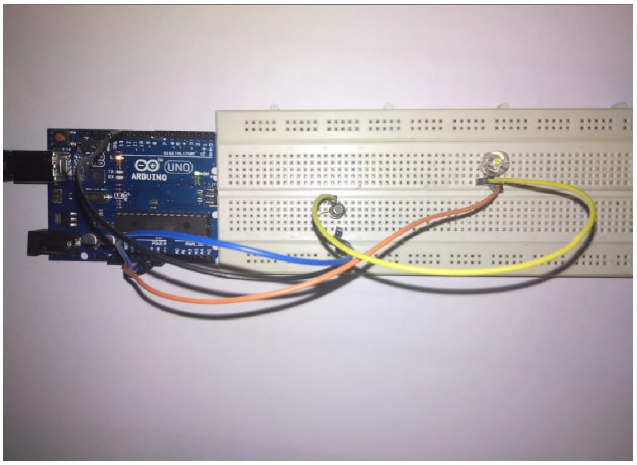

Fig. 10.Output of Transmitter

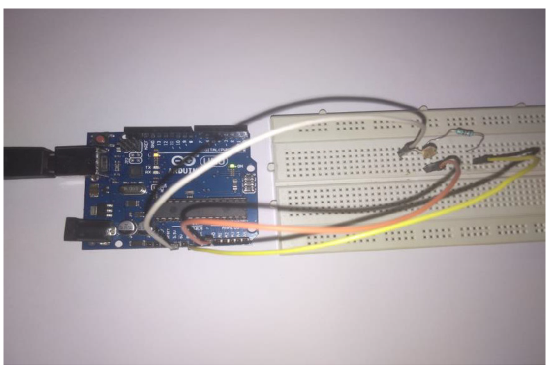

Fig. 11.Output of Receiver

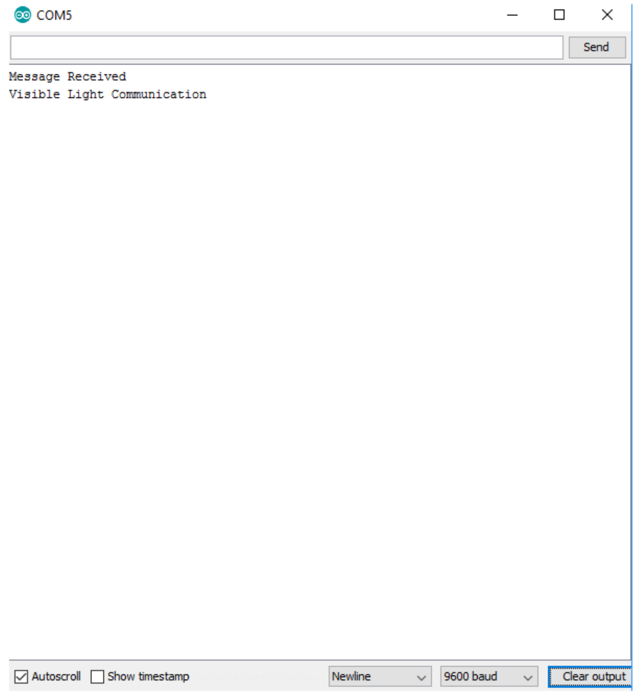

Fig. 12.Received Data

Both systems were tested for different data rates and at different distances up to 1.5 meters. After 1.5 meters the receiver was not able to receive any data. For the system without Manchester coding, the highest speed at which the receiver was able to receive data was 500bits per second or 62.5 Bytes per second. For the system with Manchester coding, the highest speed at which the receiver was able to receive data was 100bits per second, this is because ofthe fact that for Manchester encoding1 bitis divided into two equal halves which are then transmitted separately. The VLCsystem is capable of receiving the same amount of data till the receiver is able to detect the variation in signals from the transmitter. In this case the distance till it can detect is 1.5 meters. After 1.5 meters the receiver is not able to interpret the incoming signals and no data is received. The measurements were taken at different distances ranging from 10 cm to 100 cm for different data rates. The results show an increment in the Data Lost during the transmission is increased as the data rate is increased. The system is not acceptable for a data rate higher than 500 bits/seconds. The percentage of data lost while transmission is increased as the data rate is increased, which is between 60 – 70 %.

3.2 Three Nodes with and without Manchester coding

Here the results obtained on addition of a third node is discussed. The total distance from Node A to Node C is 2.5 meters. The data lost during the transmission is increased as the data rate is increased. But one point to be noted here is that the amount of data lost while using Manchester coding scheme is higher than that of without using it. This is because of delay caused by microcontroller while processing the data which causes loss of synchronization resulting in more data loss. Here the four channels represent the output from the two transmitters and the two receivers.

IV.CONCLUSION

Visible Light Communication is the rapidly growing segment in the field of optical wireless communication.There are many advantages to this rapidly growing field but there are many challenges also. It is still an emerging filed but improvements are being made rapidly.The two differentmethodsfor implementing Visible Light Communication i.e. (OOK with Manchester Encoding and OOK without Manchester Encoding).Furthermore, the system was extended by adding additional transceiver node for evaluating its scope as a wireless sensor node. From the results obtained it can be concluded that implementing the system by using just OOK modulation have certain advantages like higher data rate, easy synchronization and less error but this modulation scheme alone cannot solve the purpose of incorporating this system in the present infrastructure and using it as a light source because it cannot solve the issue of flickering of light. While using this modulation scheme along with Manchester encoding scheme which is the second method, solves the issue of flickering. But it needs a better synchronization mechanism.

V. FUTURE SCOPE

5.1 Improving the synchronization in Manchester coding:

A pre-defined timer was used for the purpose of finding the mid-point of the signal and for synchronizing the transmitter and the receiver. Though by using this method the system works fine but it is susceptible to loss of synchronization which causes loss of data and adds some error values. This can be improved by using interrupts, triggers, flags and Interrupt Service Routine in the microcontroller. Using interrupts will not only improve the synchronization, it will also make the system more power efficient.

5.2 Error Control:

An error control mechanism can be added to the system by using an error handling mechanism which will help to detect and correct errors that occur during the transmission.

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