Text Data Transmission from PC to PC via Laser-based Visible Light Communication

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Abstract

The global economy relies on the growth of new industries as a result of technological advances. The phenomenal rise of wireless communication systems over the last two decades, along with rising demands on wireless data traffic, has reduced the availability of the limited and costly RF spectrum, necessitating the invention of additional wireless transmission techniques. This gives birth to Visible Light Communication (VLC) which has been identified as an essential part of communication technology for the 5G network. This paper aims to build a wireless VLC system that can send text data between two computers using visible light. The transmitter is a Laser Diode (LD), the transmission medium is air, and the receiver component is a Light Dependent Resistor (LDR). As the LD Flickers rapidly on and off, text data is transferred as strings of 1s and 0s. The LDR receives this binary data, converts it into a suitable format, and displays it on the serial monitor screen. For proper data transmission and receiving, both hardware (ArduinoUnomicrocontroller) and software (ArduinoIDE) are necessary. The proposed system performance is tested under changing the distance between transmitter and receiver. The evaluation results demonstrated that the data baud rate is better with the proposed system than the others, where it reached more than 2000000 bps with an accuracy of 100% across a distance up to 21 m with unlimited characters. In addition to some of its potential applications in the industrial Internet of Things (IoT), vehicle communications, aviation, hospitals and healthcare and underwater wireless network applications.

Keywords: *Visible Light Communication, Li-Fi, Laser Diode, Light Dependent Resistor, Optical wireless communication, Text, Arduino*

1. Introduction

The Internet has made life easier. This technology has also given civilization a fresh lease on life. The internet has helped to improve the planet as a whole. Wireless Fidelity, commonly known as Wi-Fi, is widely used nowadays. Wireless internet has become mainstream and, in its way, has revolutionized the globe. Wi-Fi users are quickly growing in various nations. The majority of Internet connections are either mobile communication or wireless connections. But looking at the Wi-Fi speed, we are still fighting because with advancements in technologies 26.3 Mbps as an average speed is not enough to work on. We need new technology to take over Wi-Fi for better speed and connectivity. Also, we need a technology which is more secure and provides more efficiency. Wi-Fi works on Radio Frequency of Electromagnetic spectrum which is less in order when compared to Visible Region. The disadvantages of Wi-Fi can be overcome by VLC also called Light Fidelity (Li-Fi)[1].

At the TED Global Conference in Edinburgh, Scotland in 2011, Prof. Harald Hass presented VLC to the world. VLC can be concisely defined as Data Transmission through Illumination [2]. Many researchers are interested in VLC technology since the Internet's lightning speed, security, availability, and efficiency compared to existing conventional wireless technologies like Wi-Fi, Bluetooth, Wi-max, etc., which use radio frequency spectrum is a greener, more secure, and cost-effective way of communicating on the planet[1].

This paper aims to build VLC system that transmits text data effectively based on the Arduino microcontroller. A basic system is given in this paper, which employs two Arduino UNO boards, LD as a transmitter, air as transmission medium, and an LDR as a receiver [2]. Light sources emitting in the visible band of the electromagnetic spectrum, such as LD and LED, can be used to transmit data. These sources can achieve higher data speeds while still providing effective illumination[3]. Although LEDs have been usually used as transmitters in VLC, the rising need for higher data speeds in the gigabit-class has shifted attention to LDs as potential VLC sources due to their unique characteristics of high modulation bandwidth, efficiency, and beam convergence[4].The paper is organized into five sections. Section (1) gives an introduction and section (2) discusses the significant existing research works on VLC. Section (3) discusses the proposed system. Section (4)is supported with the research results and compares them to a set of results from the literature review, followed by the conclusion with future work section.

2. Literature Review

There has been a lot of research done with VLC technology in the last several years, trying to use its different features to become an alternate transmission medium for wireless data transfer[5].A visible light communication system between two personal computers has been built utilizing Arduino microprocessors in this paper [2]. This system has the ability to send and receive data up to 18 characters across a distance up to 6 cm.In[6], the authors described how to build and test a Li-Fi module for transmitting and receiving text data. By utilizing LDR as the detector, it is feasible to achieve text data transmission distances up to 2m. The authors of [7], built a Li-Fi based wireless communication system using VLC, where the transmitter part is comprised of an array of LEDs connected to an ArduinoUno circuit, while the reception section is comprised of an array of PNP diodes (BPW34) wired to an ArduinoUno circuit. Because of ambient light penetration, the current effective data transmission speed is 100 bits/sec, with a distance between transmitter and receiver no more than 1 foot.

In [5], the authors devised a VLC-based system for transmitting data between two cellphones. This system is comprised of two parts: a transmitter and a receiver. The built-in smartphone camera's flashlight is utilized in the transmitter section to transfer binary data by turning the flash on/off, on if the binary data is 1, and off if the binary data is 0, according to the On-Off Keying (OOK) modulation method. There is an ambient light sensor in the receiver section, which is used by the built-in smartphone sensor to detect the flickering of the flash (on/off). The maximum distance between the transmitter and receiver was 15 cm, and the system achieved a low data bit rate of about 9 bps. The authors of [8], built a wireless system that used Li-Fi technology to transfer text data between two computers at a rate up to 147 bps across a distance 20 cm. In [9], a Li-Fi module for transmitting and receiving text information has been built and tested successfully. It is possible to achieve text knowledge transfer of up to 2 meters

Moreover, in this paper, a wireless communication system is developed that utilizes a VLC technology to transfer text data between two computers, which achieves a high data transmission rate. While the system performance is tested by changing the distance between transmitter and receiver. The proposed system comprises the transmitter part and receiver part. In each part, there is an ArduinoUno circuit, one connects to the transmitter PC, and the other connects to the receiver PC. Besides, the proposed system utilizes an LD as a source to transfer data, and a LDR to sense the light data and convert these data back into the original format. The evaluation results demonstrated that the data baud rate is better with the proposed system than the others, where it reached more than 2000000 bps with an accuracy of 100%across a distance up to 21 m.

3. Proposed System

A proposed system model as displayed in figure[1], Two PCs (one for transmission and one for reception), two ArduinoUno microcontrollers on both ends, anLDat the transmitter end, and the LDRat the receiver endThe PC is interfaced along with the Arduino UNO, which is connected to the LD at the transmission end. The Arduino causes the LD to flicker rapidly at a speed that is unnoticeable to the naked eye. The LDR is interfaced with the Arduino, which is connected to the PC, on the receiving end. The flickering is caused by the message being transmitted and the information it contains. The LDR acts as an optical sensor, picking up these voltage variations, which the Arduino board then translates into the message being sent.

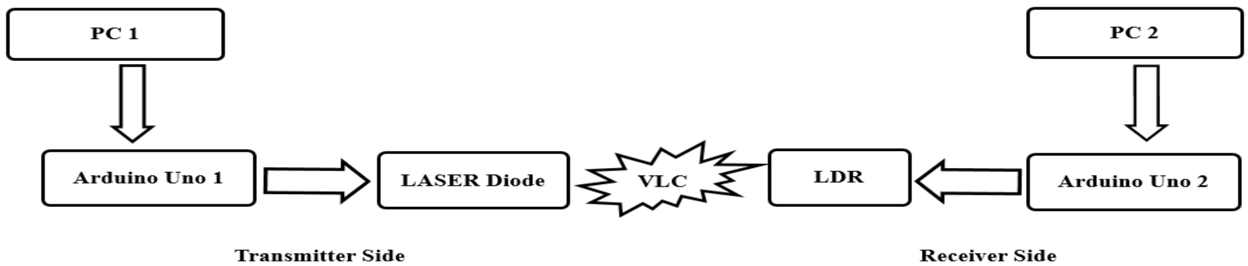

Figure1. Block Diagram for data transmission between two PCs using Visible Light Communication

In this paper, some text will be sent from one PC to another using light. The LD acts as the data transmitter and on the other side, the same data will be received using the LD. Therefore the following circuits are designed and implemented for the proposed system.

3.1 Arduino Setup

The ArduinoUno used is an ATmega328 microcontroller operating at 5V. It has 14 digital pins and 6 analog pins. It has 2KB SRAM and 1KB EEPROM. It operates at 16MHz clock speed. The serial communication port on the Arduino board is used to load programs from a computer into the board. To program the Arduino, the Arduino IDE was used. The Arduino was programmed to do a variety of activities, including turning on and off the LD in the transmitter's circuit as well as reading the analog signal in the receiver's circuit from the LDR. The Arduino board served as both the microcontroller and the power supply unit (PSU) for the circuits to avoid making the system redundant. When connected to the PC through the serial connection cable, it produces a voltage of around 5V from its port and also serves as a virtual ground [10].

3.2 A Transmitter

The main components which are used in the transmitter part of the proposed system are shown in Fig. 2 and listed as follows: ArduinoUno microcontroller, Arduino Serial Monitor, Breadboard, tactile switch, resistor 220 ohm, 650nm red dot Laser Diode, Jumpers and Arduino IDE as a software of the proposed system.

3.2.1 Hardware Design

AnLDis connected to a resistor in this circuit. Since the resistor aids in current limitation, preventing the LDfrom burning out, as illustrated in Figure [2].

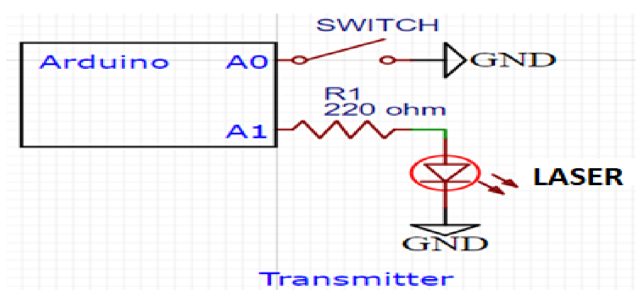

Figure 2. Transmitter circuit design using EasyEda program

3.3.2 Hardware implementation

After the circuits design, all the components of the circuits were implemented on a breadboard carefully with the aid of jumper wires. PC 1 is used on the transmitter side; this computer acts as the data source. The pin A1 of the Arduino board is connected to a LDas shown in Figure [3], and is defined to act as an output. A serial port object associated with serial port COM5 of the Arduino is generated. The baud rate is set to 2000000bps, which is the number of signal or symbol changes per second. The Arduino is then linked to the serial port object. A computer code written in Arduino IDE software contains the string input and generates its corresponding binary bit stream. A high or a low value is written to the A1 pin.

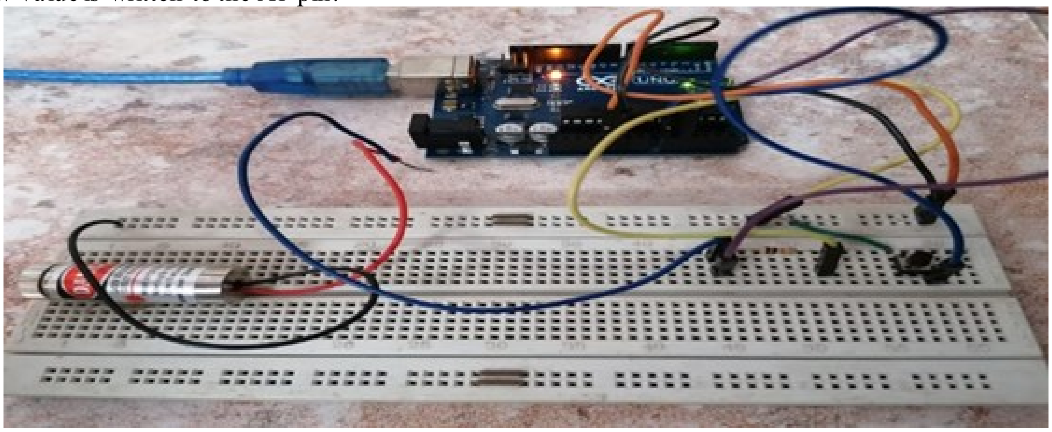

Figure 3.Transmitter Circuit on Breadboard

3.3.3 A Transmitter Threshold Tuning

Set the pins for the LD and the switch (push button) on the transmitter to A1 and A0, respectively, as illustrated in figure [2]. The pin mode of the LD and the button is set to output and input pull up, respectively. Read the button's state and reflect it on the LD, therefore use the digital read function to read the state of the button and the digital write function to write the state of the button on the LD.

Algorithm 1: Algorithm for Threshold Tuning at Transmission end

1: Start

2: Set A1 pin for the LD to behave as an output.

3: Set A0 pin for the button to behave as an input pull up.

4: digitalRead () function to read the button's state.

5: digitalWrite () function to write the button state on LD.

6: Stop

3.4 Communication Protocol

A communication protocol is necessary to send the data. The communication protocol is a set of rules that the transmitter and receiver agree upon to ensure that the data transmitted is properly understood. Bit-by-bit transmission is one technique for data transmission. Let's say we want to send this byte (0b11010110). We can start from the left and proceed in this way. The waveform of this byte looks like Figure [4].

Figure 4.The Wave Form of Binary Data

This data does not contain enough information to properly understand the data on the receiver side. The information that is missing is when the data must be sampled, so the signal that will tell the receiver when it must sample the data must be sent. These rising edges correspond to that time, and now when the data is sampled, it is sampled correctly, and the byte that is received is also correct. This method requires us to send two independent data waveforms, as shown in Figure [5], but the circuit must be as simple as possible.

So, one compromise that we can make is to send the data in this way, let us say that the transmitter and the receiver agree upon the time period in which one bit is sent. Let us imagine that at the red vertical edges located in the middle of the bit's time period, the clocks are synchronized from these edges as shown in Figure [6]. It only needs the receiver to wait one time period and sample the data every time waiting one period. Therefore the data is sampled correctly however we still are lacking a way to synchronize both clocks, for that red edges of the signal comes into play. In the beginning, the receiver is in an idle state when there is no transmission and when it recognizes this falling edge it knows that the data transmission has begun from this point it waits 1.5 time period. It is a 1.5 time period because one period should be low and a further half period is required so that we are right in the middle of the data transmission. After this step, the receiver can wait one time period every time sampling and waiting one time period then the data is received correctly. This rising edge at the end of the tra nsmission, as shown in Figure [6], is just to make sure that when this transmission ends the voltage is high, so that this falling event can be recognized.

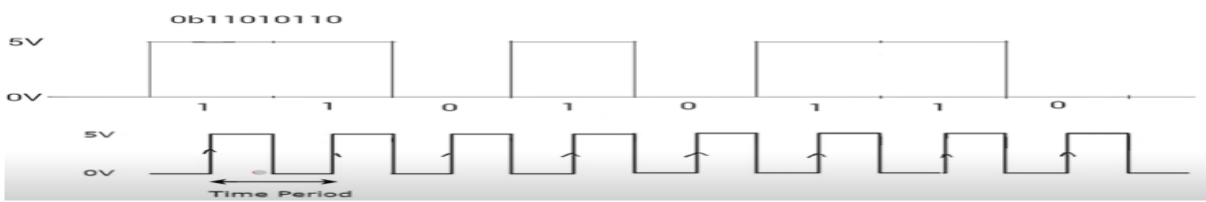

Figure 5.The data waveform with clock waveform for the synchronization between the Transmitter and the Receiver

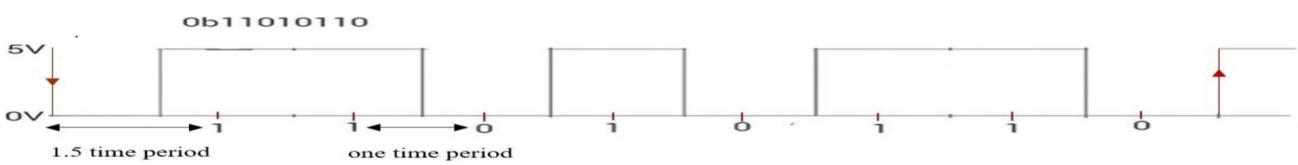

Figure 6.Synchronization between the sender and the receiver

3.5 A Transmitter Algorithm

For the transmitter code. Type the string that we want to send then determine the length of it. Create a function that will transmit the data according to the protocol, Send_byte is a function to transmit only one byte as an argument. Pass the byte that we want to send according to the protocol. Need to make sure that the voltage is low for one period. Following that, the bits will be transmitted, and once completed the voltage will be high. Sending one bit at a time depending on the byte we want to send needs using two bitwise operations one of them is AND operator (&) and the other is shift operator (<<). AND operator performs the operation bit by bit so for example we have (a) & (c) as shown in figure [7], the computer looks at each bit, one at a time, and apply the AND operator so zero AND one is zero, zero AND anything is zero. In the second example if we have something like this 0 & 0 will be 0 but 1 & 1 will be 1. In this way, we extract a specific bit and ignore everything else so wherever we put one will appear at the output and anywhere we put zero will disappear so irrespective of whether it is one or zero the answer will be zero. It would be a very suitable way if we could somehow select a specific bit that we want. we can do that by using shift operator so this number is just the hexadecimal representation of this number 0x01 and will be our mask c as shown in figure [7] if it is shifted by i and then AND this number with (a) which is our original byte we will only get that bit and everything else will disappear. we are looking at the zeroth bit and if we in this case i is zero but for example, if i was to be one then this would be shifted by one and this would be like this (00000010), when we add it by any byte we get only the second bit and so on. we want to see if the bit is one or not so the answer will get after basically taking the byte that we are trying to transmit and the mask that helps us to extract a specific bit we can see whether this number is zero or not so if this (Out! = 0) is not zero then consider this as a one and will turn on the LD, if this was zero then we will keep the LD off.

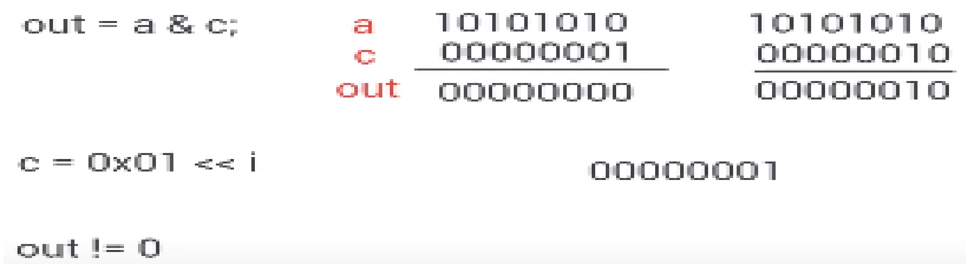

Figure 7. Example of bitwise operations (AND operator and shift operator), and shifted mask

Algorithm 2: Algorithm for Arduino IDE at Transmission end

1. Start
2. Define the string and the string length variables.
3. Determine the length of the string that we want to send according to the communication protocol by using strlen () function.
4. Use for loop (int i = 0; i < string_length; i ++) to send the string characters.
5. Delay (1000 ms).
6. Use send_byte () function to transmit only one-byte at a time as an argument
7. Use digitalWrite () function on LASER pin to make sure that the voltage is low as falling edge.
8. Delay () one period according to the communication protocol.
9. Pass the byte that we want to send.
10. Use for loop (int i = 0; i < 8; i++) to send bits of our byte.
11. To send one bit at a time we need to use two operations one of them is a bitwise AND (&) operator to extract a specific bit and ignore everything else, and the shift operator (<<) to select a specific bit that we want.
12. Produce our mask, it will be 0x01 and we will shift it by i.
13. Anding the result of shifted mask with our byte.
14. If the result of Anding operation is not equal to zero then consider this as one.
15. Use digitalWrite (LED_PIN, (my_byte & (0x01 << i))! = 0) function to write the final result of operations on LASER if not equal to zero.
16. Delay () for one period otherwise it could be too fast for the receiver to recognize transmitted bits.
17. Use digitalWrite () function to write high on LASER after transmission end according to the communication protocol.
18. stop

3.6 A Receiver

The main components which are used in the receiver part of the proposed system are shown in Fig. 8 and listed as follows: ArduinoUnomicro controller, Breadboard, tactile switch, resistor 220 ohm, LDR- 5 Ohm, Rotary potentiometer - 10kohm, Jumpers and Arduino IDE as a software of the proposed system.

3.6.1 Hardware Design

Figure [8] shows a voltage divider circuit in which the more light striking the LDR, the higher voltage is gained.

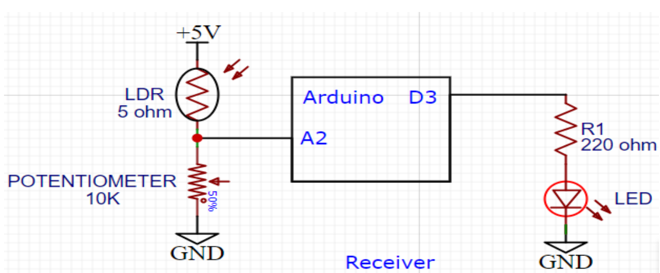

Figure 8. Receiver circuit using EasyEda program

Figure 9.The LDR resistance versus the elimination

Let's have a look at how this works theoretically, so in Figure [9], a curve of LDR resistance versus elimination [11].

Figure [9], shows that when the amount of light an LDR is exposed to increases, its resistor decreases, and vice versa.

As shown in Figure [10],the voltage at the red point is displayed versus the resistance R1

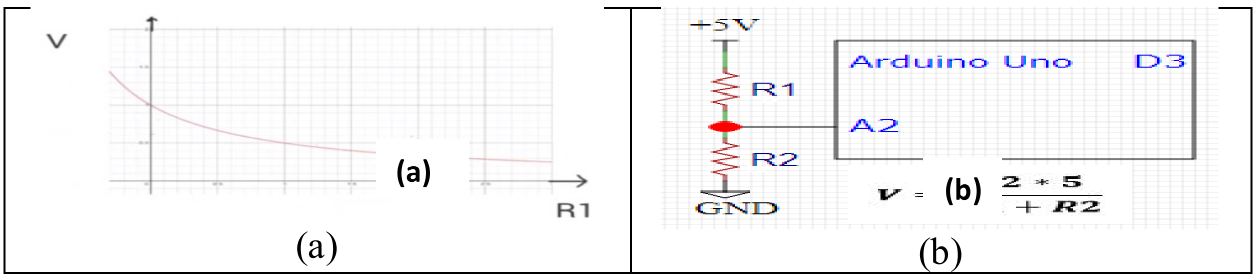

Figure 10. (a) The voltage at the red point versus the resistance R1 (b) the voltage divider circuit.

Figure [10] shows that as the amount of light falling on the resistor rises, the voltage increases and the resistance drops.

3.6.2 Hardware Implementation

A USB cable is used to connect an ArduinoUno board to PC 2. The analog pin A2 of the ArduinoUNO2 is connected to the LDR,as shown in Figure [8]. The LDR is setapproximately 6 meter away from the LD, ensuring that they have a direct line of sight. Since its resistance changes with variations in the amount of light falling on it from the LD, the LDR detects rapid flickering of the LD while transmitting 0 or 1.

Figure 11.Receiver Circuit on Breadboard

3.6.3 A Receiver Threshold Tuning

Set the pins for the LED and the LDR on the receiver to be pin 3 and A2, respectively as illustrated in figure [6]. Then pin mode of the LED is set to be output. Since analog voltage will be read from the LDR, create a function named get_ldr () that determines if the voltage is above or below a certain threshold. An initial value for the threshold should be defined, which will be altered if it does not work. The data reported by LDR is compared with predefined threshold value, which is 100 lux (set by experiment), to identify whether this data represents bit 1 or 0. This is the first stage, so test it by uploading the code to both Arduino with adjustment of the Rotary Potentiometer.

Algorithm 3: Algorithm for Threshold Tuning at reception end

1: Start

2: set pin 3 for the LED to behave as an output.

3: set A2 pin for the LDR.

4: define an initial value for the threshold variable which is 100 lux (set by experiment).

5: get_ldr () function to tell us if the voltage is above a predefined threshold or not

6: The data reported by LDR is compared with predefined threshold value, which is 100 lux (set by experiment), to identify whether this data represents bit 1 or 0. .

7: digitalWrite () function to update the led depending on the data reported by LDR.

8: stop

3.6.4 A Receiver Algorithm

The procedures from the transmission code will be repeated for the reception code, but in reverse. Create a function named get_byte. It retrieves the byte according to the standards that we have set according to the communication protocol. The first step inside this function waiting for a 1.5 period time then for () loop for eight-time to receive bits of the byte. Therefore, start with having a byte in which the data is filled, initially, it will be zero. Then read the signal from the LDR and sample it, we'll put zero if the value is zero, but one if it's one. Once this loop is complete, the whole data that was in the transmission is recovered, following that waiting for one period according to the communication protocol. Get_byte function is called as soon as the receiver recognizes the falling edge. The falling edge recognition requires two variables to be defined previous state and the current state then check if the current state is low and the previous state was high this means this is a falling edge. The serial port of the Arduino can be used to see what's happening so initialize the serial port and choose the baud rate as 2000000bps, which means that the serial port is capable of transferring a maximum of 2000000 bits per second. Create print_byte function to print the received byte as an argument and inside it convert this byte into a string. This function returns the byte, interpret it as a character, and store it into a buffer as a string. To print the received data from the buffer, use the serial print command.

Algorithm 4: Algorithm for Arduino IDE at Reception end

1. Start
2. Recognize the falling edge by defining two variables previous states and current state
3. Use if condition (!current_state && previous_state) if the current state is low and the previous state was high this means this is a falling edge
4. Call get_byte () function to retrieve the byte according to the communication protocol.
5. Have a byte in which the data will be filled initially it will be zero (char ret=0).
6. Delay 1.5 times of period according to the communication protocol.
7. Use for loop (int i = 0; i < 8; i++) to retrieve bits of our byte
8. Read the value of the LDR and sample the signal that we receive using get_ldr () function to tell us if the bit is one or zero.
9. The result of get_ldr() function is shifted by i to order its position in the ret variable
10. Use a bitwise OR between The result of get_ldr () function after shifting with initial value of the ret variable (zero) because it will not change the original value since zero orbit anything is the original value.
11. Delay () one period.
12. Initialize the serial port with baud rate 2000000 to see the receiving data.
13. Use print_byte () function to convert the received byte into a string.
14. Store the received data into buffer.
15. Use Sprint (buff, "%c", my_byte) function to return and interpret the received byte as a character and store it into this buffer as a string.
16. Use Serial.print (buff) function to print the data that is inside the buffer.
17. Call print_byte function () beside get_byte () function to be it's an argument since print the byte that we get.
18. stop

4. Results & Discussion

As illustrated in figure [12], the hardware setup for the transmitter and receiver is used. On the Right-hand side is the transmitter with Arduino microcontroller and LD to transmit the text data through light. The left-hand side is the receiver with LDR which is connected to the Arduino microcontroller. The proposed system has been built successfully to transfer text data from one computer to another. The transmission is based on simplex channel condition and direct line-of-sight (LOS) assumptions. Tests were performed in indoor ambient light (both natural and artificial light). The result of implementing the entire system (transmitter, receiver, and software) is displayed in Figure [13], Receiver serial monitor displays the received data. When the angle between the receiver and the LD's LOS changes, the data received is impacted. The proposed system is used to send and receive a single character in the first stage. In the end, unlimited characters are sent and received successfully. In the initial stage, the distance between the LD and the LDR is set to one meter, which extended to 21 meters in the end. The distance can be increased while maintaining the alignment between the LD and the LDR. The ambient light of the workplace is one of the environmental elements taken into account. We'd have to adjust the LDR's threshold consideration in high light room, and the distance between the transmitter and receiver would have to be decreased for better focus. The baud rate can be manually modified in the Arduino IDE; in this work, a 2000000bps baud rate was obtained, indicating that the transmission speed is adequate to prevent lagging.

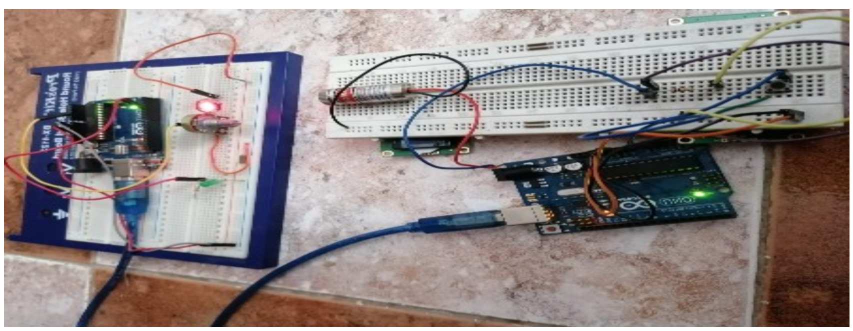

Figure 12.Hardware setup for the experiment with Arduino transmitter and receiver along with LD andLDR

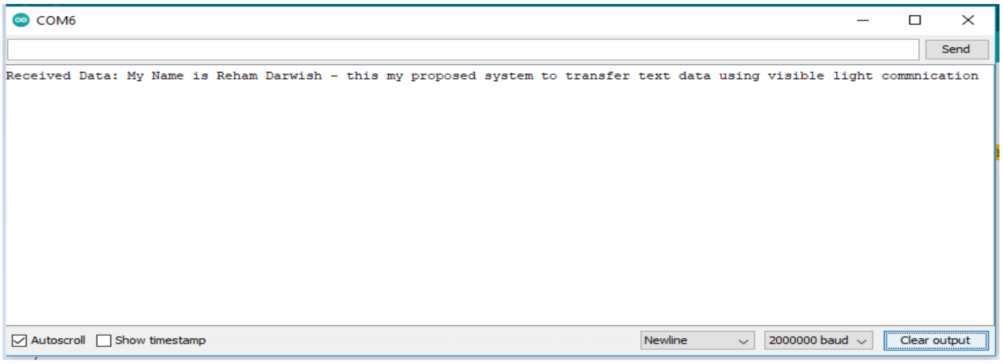

Figure 13.Receiver Serial Monitor Displays the Received Data

For the evaluation process, a comparison, shown in table [1], is made between previous related works and the proposed system. The symbol (-), shown in the below table, refers to the related works that did not mention either data rate or distance.

This work differs with respect to similar works as in [2], [12], [6], [7], [5],[8] and [9] in the following. In [2], it can transfer only 18 characters but in the proposed prototype unlimited characters are sent and received successfully. In [11], achieved 9600bps as a baud rate but in the proposed prototype the baud rate of 2000000bps is achieved. In [6], [7], [5], [8] and [9] the achieved distance is no more than 2 meters but in the proposed prototype 21 meters is achieved as a distance.

Table 1.Comparison between Proposed System and Related Works

S.NO	Ref.	Transmitter	Receiver	Distance	Data rate (b/s)
1	[2]	Single LED	LDR	Up to 6 cm	(18 characters)
2	[12]	LD	photodiode	-	9600
3	[6]	SingleLED	LDR	Up to 2 m	-
4	[7]	an array of LEDs	an array of photodiodes	No more than 1 foot.	100
5	[5]	smartphone camera's flashlight	an ambient light sensor	15 cm	9
6	[8]	an array of LEDs	photodiode	20cm	147
7	[9]	Single LED	Photodetector	Up to 2 m	-
8	Proposed system	LD	LDR	Up to 21 m	2000000

5. Conclusion and Future Work

The main goal of this project is to implement a VLC communication system for text data transmission between two PCs. The proposed system performs well when tested. The proposed system construction is inexpensive, making it satisfy the project's main goal. The evaluation results demonstrated that the data baud rate is better with the proposed system than the others, where it reached more than 2000000 bps with an accuracy of 100% across a distance up to 21 m with unlimited characters. There are certain restrictions to the system as well, Multi-user access is not supported by the VLC prototype and this prototype does not provide bidirectional communication. Using an LD as a data transmitter also faces misalignment and outages issues because the line of sight between the transmitter and the receiver can be lost or blocked in various ways, this limits the usage of the VLC system as a LAN to a narrow geographical area. However, the speed and accuracy of this technology are faster and more reliable than RF wireless signal transmission. Eye safety issues are a serious concern, as long-term exposure to high-intensity light can harm human vision and circadian rhythms and modern laser diodes have light-quality issues for regular illumination purposes. In the case of using LEDs as transmitters, limiting the allowable bandwidth will limit the transmission rate in the VLC LED system; therefore, LD is a more promising alternative, providing higher bandwidth and transfer rate. For future work, to improve the data bit rate, instead of using an LDR because of its slow response time, a fast phototransistor sensor with a response time in nanoseconds may be connected to an ArduinoUno at the reception. Using a microcontroller such as ARM LPC1768, the data rate can be increased by many folds because of the ArduinoUno board clock speed is 16MHz that leads to reduce data transmission. Despite these challenges, if this technology is preferred, communication will be greener, cleaner, and more secure, and the environment will be more fulgent. In addition to some of its potential applications in the industrial Internet of Things (IoT), vehicle communications, aviation, hospitals, healthcare and underwater wireless network applications.

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